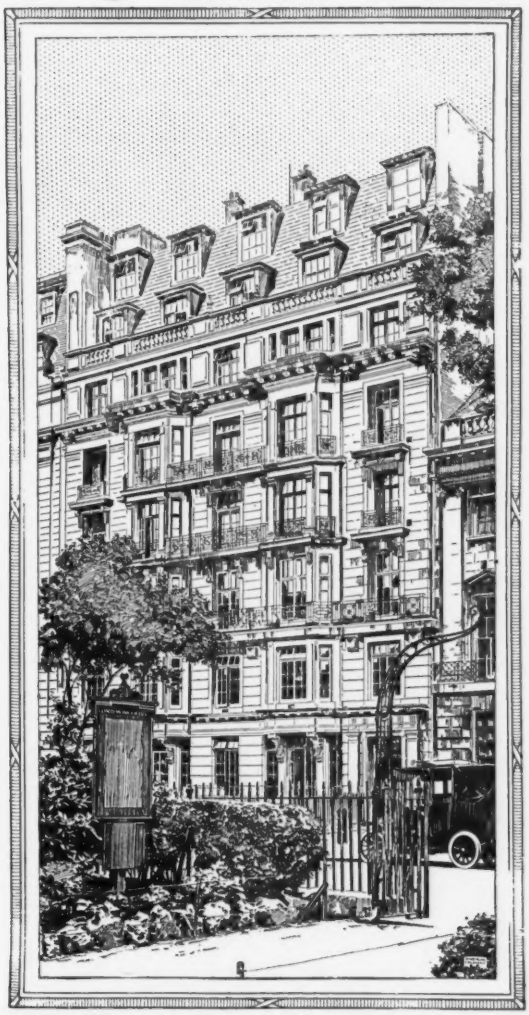
The ENGLISH ELECTRIC JOURNAL



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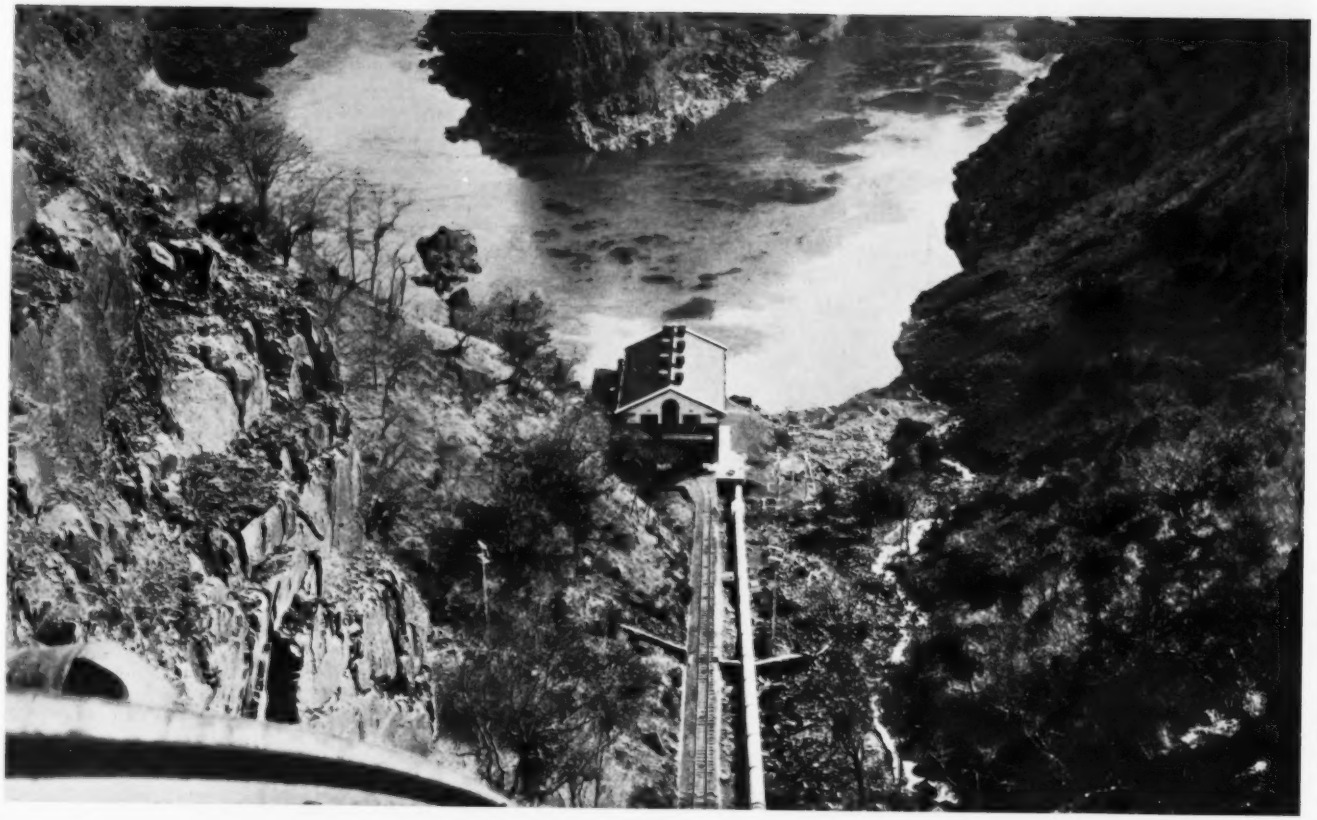

Victoria Falls Power Station and Pipeline.

HAIFA POWER STATION

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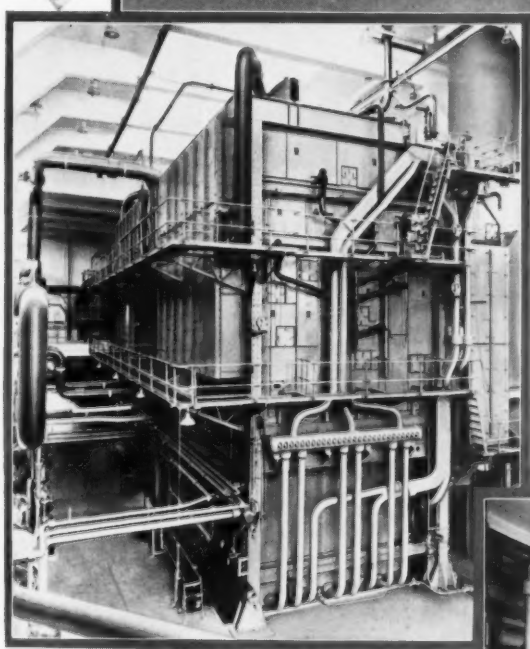

TWO B. & W. Boilers, Nos. 4 & 5, have recently been put into commission at the above Station.

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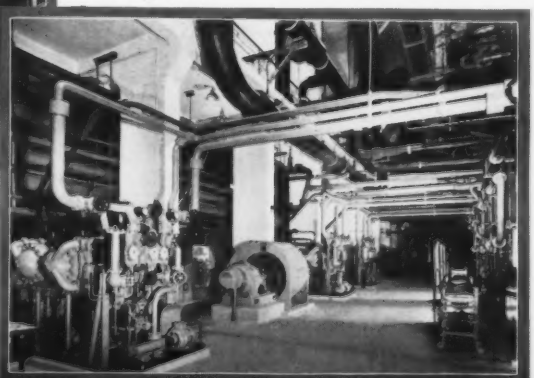
The illustrations show :

Top : An aerial view of the Power Station.

Centre : A view of the Boilers.

Bottom : Pumping and Heating Units, Fans, and Firing Aisle.



Two similar B. & W. boilers, each with a normal evaporation of 70,400 lb./hr. at 842°F. and 385 lb./sq. in., have also been installed in the Reading Power Station of The Palestine Electric Corporation Ltd.

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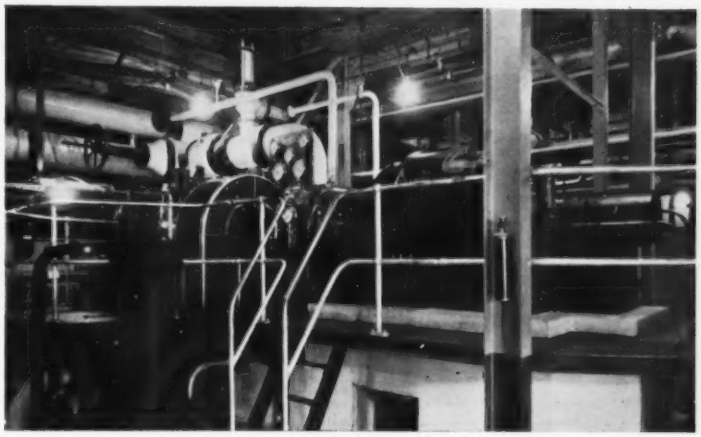

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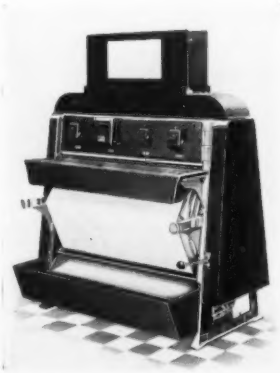

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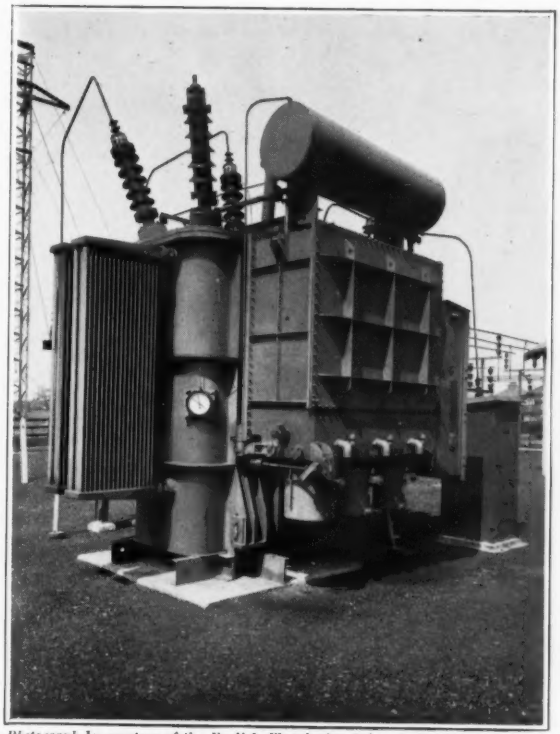

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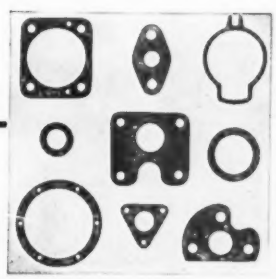

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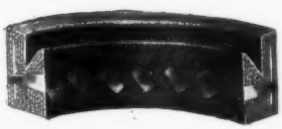

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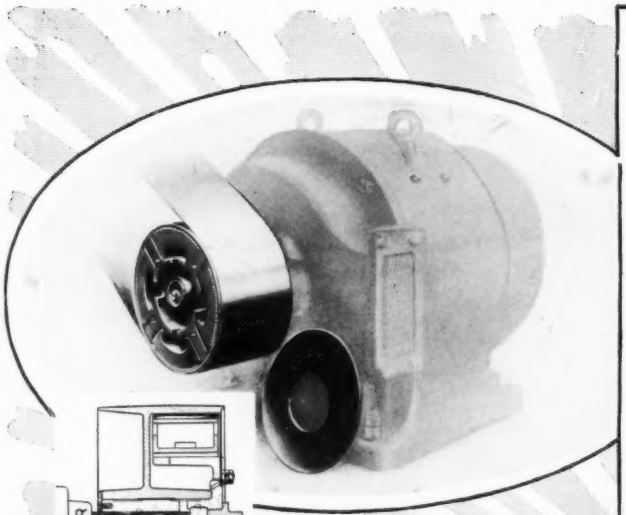

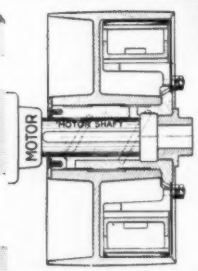

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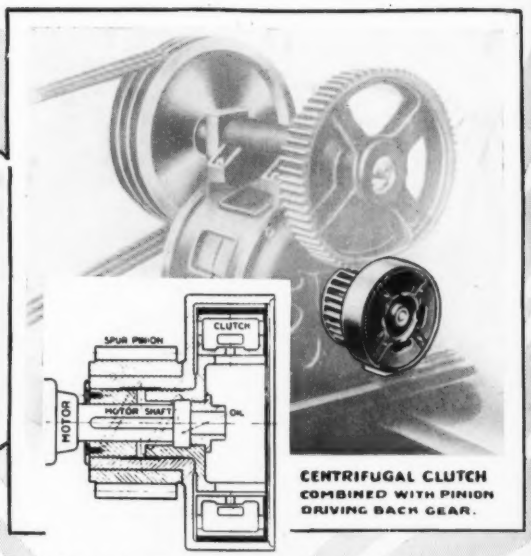

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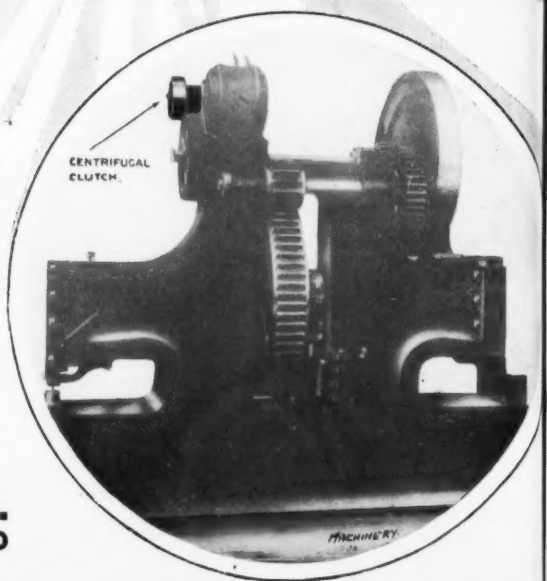

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The English Electric Journal

Vol IX. No. 7 OCTOBER/DECEMBER, 1939. One Shilling.

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All Communications respecting Editorial Contents should be addressed to THE EDITOR, THE ENGLISH ELECTRIC JOURNAL, THE ENGLISH ELECTRIC COMPANY LIMITED, STAFFORD.

EDITORIAL.

The Company's ability to execute comprehensive Hydro-electric contracts in any part of the world is once again exemplified in the first article in this issue, contributed by Mr. H. L. Bazalgette, which describes the Victoria Falls Hydro-electric Scheme. Although the generating plant is only of medium capacity, the scheme is nevertheless of particular interest in that it is the first to be undertaken at these celebrated falls, and furthermore, the sets are entirely automatic in operation. The article describes the Water Turbines and Generators and the automatic operation of the plant, and concludes with an account of some exploratory work carried out at the Falls by the Company's Resident Engineer, which we believe will be of general interest. Owing to the remote site of the Power Station, and to the trying climatic conditions, the installation of the plant presented more than usual difficulties.

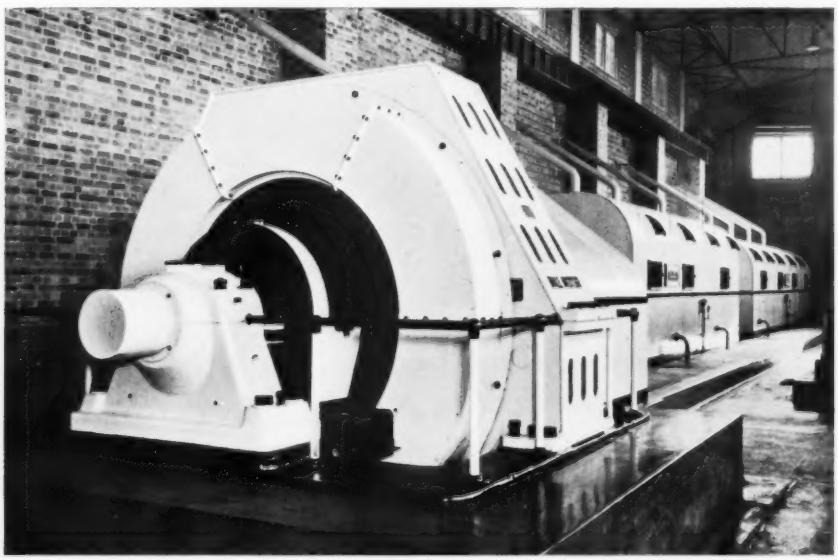
At the present time the Company has in hand plant aggregating some hundreds of thousands of horse power for Hydro-electric schemes in New Zealand, Tasmania,

India and on the River Liffey, in Eire. In carrying out this work the Company is playing no small part in assisting the policy of the Government to maintain the export trade of the Country.

In the second article, entitled "The Thermodynamic Trend of Steam Turbine Practice," the joint Authors, Mr. J. P. Chittenden and Mr. J. T. Moore, discuss the various factors to be considered in connection with the adoption of high steam pressures and temperatures in steam turbines. It is pointed out that due to improvements in materials and machine tools, turbines for high temperatures and pressures are now a thoroughly sound and commercial proposition, though load conditions in this country do not justify their more wide adoption at the present time. In the future, however, as conditions change, higher pressures are likely to come into more general use.

The Company has supplied a very considerable amount of plant and apparatus to the Ebbw Vale Steel Works of Messrs. Richard Thomas & Co., Ltd., and in the last article in this issue Mr. H. S. Carnegie gives a description, accompanied by illustrations, of the equipment supplied for the wide strip hot mill. The article commences with a brief account of the production of sheets from ingot to strip, followed by a description of the main driving motors, motor-generator sets, control equipment and coilers. As an indication of the magnitude of the plant it may be mentioned that it includes machines giving a peak total of over 100,000 h.p. Features of other parts of this plant, and of the control gear in particular, will be described and illustrated in future articles.

In conclusion, we would advise our many readers and advertisers that, due to present conditions, the Company has decided, as a temporary measure, and as from this issue, to publish this Journal twice yearly, instead of quarterly as hitherto.



6000 B.H.P. (continuous rating) Split Frame, Slipring Induction Motor having 100% overload capacity at 6,600 volts 50 cycles, driving a Morgan continuous billet mill at the Port Kembla Works of Australian Iron and Steel Limited.

The Victoria Falls Hydro-Electric Scheme.

By H. L. BAZALGETTE, A.C.G.I., A.M.Inst.C.E., A.M.I.E.E.

The Victoria Falls and Transvaal Power Company has recently completed a very successful hydro-electric scheme at the Victoria Falls on the Zambesi River, and though this development is small in capacity, it is of particular interest since it is the first to be undertaken at the famous Falls and is completely automatic.

About 30 years ago a proposal for supplying the Rand with power from the Victoria Falls was studied, the overhead transmission line was to be 700 miles in length, and the pressure 150,000 volts. Owing to technical difficulties this project could not be realised at that time, but the Power Company retained its right to develop the power at the Falls if required at some future date, and the scheme just completed is the outcome of that arrangement.

The generating station is situated in the third gorge, known as the "Silent Pool," at a hairpin bend in the river about two miles downstream from the Falls, and its location is shown on the map in Fig. 1. It contains two 1,000 kW. automatically controlled units, the purpose of which is to generate power for transmission over a distance of about seven miles to the town of Livingstone, until recently the capital of Northern Rhodesia, and also over a distance of about two miles to the Falls Hotel which, with the generating station itself, is in Southern Rhodesia.

Towards the end of 1936, a comprehensive contract was placed with The English Electric Company for the power station and substation equipment to the arrangement and specification of the London Engineering Department of the Power Company, comprising water turbines, generators, transformers, switchgear, cables, etc.

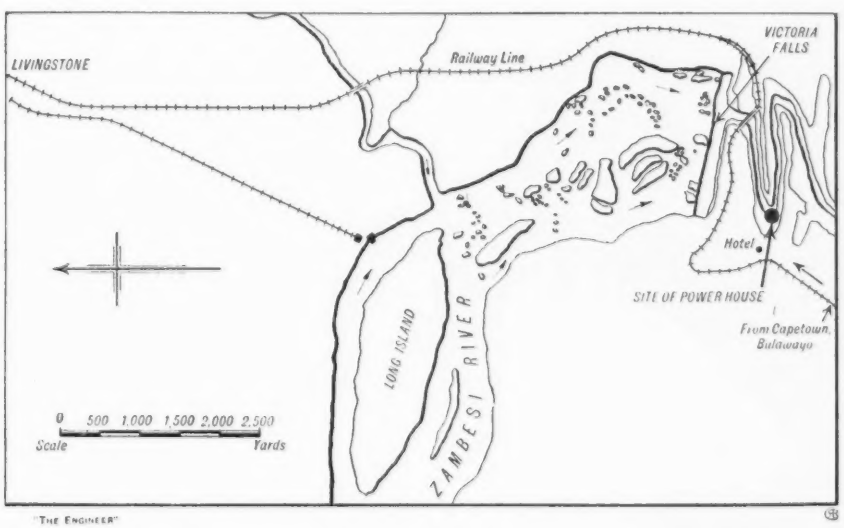
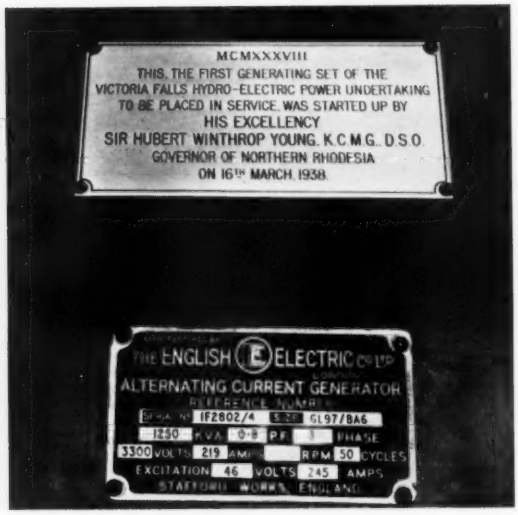


Fig. 1.—Map showing the location of the Victoria Falls Power Station.


MCMXXXVIII
THIS, THE FIRST GENERATING SET OF THE
VICTORIA FALLS HYDRO-ELECTRIC POWER UNDERTAKING
TO BE PLACED IN SERVICE WAS STARTED UP BY
HIS EXCELLENCY
SIR HUBERT WINTHROP YOUNG, K.C.M.G., D.S.O.
GOVERNOR OF NORTHERN RHODESIA
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3300 VOLTS 219 AMPS RPM 50 CYCLES
EXCITATION 46 VOLTS 245 AMPS
STAFFORD WORKS ENGLAND

Fig. 2.—Tablet affixed to one of the generators to commemorate the starting up of the Station.

On 17th March, 1938, the new power station was opened by Sir Hubert Young, K.C.M.G., D.S.O., Governor of Northern Rhodesia, who by pressing a button, started up the first unit under automatic control, and Lady Young afterwards switched in the supply to Livingstone.

This historic event, which marked an important step in the progress of the Colony, was commemorated by affixing the tablet, shown in Fig. 2, to one of the " English Electric " generators.

In addition to the two purposes mentioned above, the plant will be able to supply any small industries which may spring up round the town of Livingstone, and since Northern Rhodesia is a wealthy and rapidly developing Colony, Livingstone may eventually become the centre of an active industrial area.

Several factors rendered the contract more than usually difficult to carry out.

The power station site is very remote, all plant after conveyance by rail from Livingstone had to be unloaded into trucks on a narrow gauge railway and pushed by native labour some two miles to the top of the gorge. It was then lowered down a very steep gradient by a steam-operated hoist. The track, which runs beside the 42 in. diameter pipeline, is shown in Fig. 3.

The climatic conditions are damp and tropical and were exceptionally trying for the erecting staff, the engine room temperature at times reaching as much as 110° F. Such conditions were also somewhat unfavourable for the operation and maintenance of the instruments, delicate relays and other apparatus necessary for an unattended station. With the ready co-operation of Mr. N. Brooksbank, the Chief London Engineer of the Power Company, all these difficulties were, however, overcome, and The English Electric Company once again demonstrated its capacity for the successful execution of comprehensive hydro-electric work in remote places and under unpromising conditions.

Owing to the fact that the site is a famous beauty spot, great care was taken by the Power Company in South Africa to obviate disfigurement, and this has been so successful that the power station and penstock are practically hidden by vegetation from passers-by. The frontispiece to this article and Fig. 4 show the pleasing and unobtrusive nature of the building, which harmonises with its surroundings.

As already mentioned, the station is designed to run automatically and is unattended, the reason being that this type of plant is economic and efficient, also the situation of the station renders it unsuitable from the point of view of health for the prolonged attendance of operating staff. Consequently, a daily visit of inspection is all that is necessary.

The plant and equipment are of an interesting character, and a description of their principal features now follows :—

Hydraulic Equipment.

The water is conveyed from the Zambesi River to the settling tanks and forebay by means of a deep canal half a mile long. From the latter the water is drawn off through screens and an isolating valve into a single 42 in. diameter pipeline and thence to branch pipes feeding the two turbines.

The turbines are of the horizontal-reaction type, each has an output of 1,450 h.p. under a net head of 347 ft., and runs at 1,000 r.p.m. They are of

Fig. 3. Victoria Falls Power Station, showing pipeline and haulage track.

Fig. 4. View of Power Station.

the overhung type ; that is to say, the turbine runner is mounted upon an extension of the generator shaft, the complete unit having only two bearings.

The turbine spiral casing is mounted upon an extension of the generator bedplate and the combined unit is thus very rigid and compact and characteristic of the Company's hydro-electric design.

The turbine runner is made of solid stainless steel with polished streamlined vanes, and is bolted to a forged flange on the generator shaft. The spiral casing is logarithmic in form and made of special cast-iron stayed with high-tensile steel bolts located round the centre flanges. This method of staying, though costly, is more satisfactory in the case of high-pressure turbines than stay vanes cast integral with the casing, since the latter occupy much space in the water stream, and are liable to contain poor metal due to cooling stresses.

Hydraulic end-thrust is minimised by the provision of an exhaust pipe which conveys to the draught tube any leakage water passing through the gaps between casing and runner, thereby preventing the building up of pressure behind the runner crown.

Regulation is effected by well-balanced swivel gates connected by levers and links to an outside regulating ring. The links are designed to break well before the elastic limit of any major part is reached in the event of an obstruction preventing one of the gates from following the regulating ring.

The links can be held in stock as inexpensive spare parts and are easily renewable in service.

The overhung type of turbine is easily dismantled and the runner and surrounding parts can be reached by simply removing the suction bend. The bearing alignment is not disturbed in the process and there is no necessity at any time to remove the spiral casing, which is therefore cast in one piece with its bottom part embedded in concrete.

To obtain complete security and stability an amply dimensioned Michell thrust block is incorporated in the inboard generator bearing, and the bearing pedestal is tied by two strong stays to the turbine cover. Each turbine is provided with an oil-pressure governing system of the Company's standard design, which has been many times described in this Journal. It is in operation all over the world, and is completely reliable and satisfactory.

The governor actuator is mounted upon the servomotor, and the latter operates the turbine regulating ring. The servomotor is closed by a strong spring, so that an ample force to close the turbine is available under all conditions ; the opening side is under oil pressure controlled by the actuator, the area of the cylinder being sufficient to overcome the spring as well as the resistance of the turbine gates.

In accordance with the Company's recommended practice, the actuator is gear-driven from the turbine shaft, and a flexible steel blade couples the pendulum to the driving shaft. This blade renders the system self-aligning.

The oil pressure for the governor is supplied by a pump gear driven from the main shaft and an alternative supply is given by a rotary oil pump incorporated in the governor base and driven by a small water turbine of the impulse type. There is no need in the present case for an oil-pressure receiver or reservoir, since only the comparatively slow opening of the servomotor is accomplished by oil pressure, closure being effected by a spring, whilst the pump is capable of supplying all the oil required ; this is a distinct simplification.

The turbine inlet valves are of the Company's cylindrical balanced streamline type and owing to their reliability are particularly well suited to an automatic station. These valves have also been many times described, and it is only necessary to say here that the design ensures safe closure under emergency conditions without water hammer, and also balance and control by comparatively small forces practically independent of the actual discharge through the valve.

While the valve is hydraulically operated it can be electrically controlled from the switchboard either to open or close.

On the upstream side of the cylindrical balanced control valve a hand-operated sluice valve is pro-

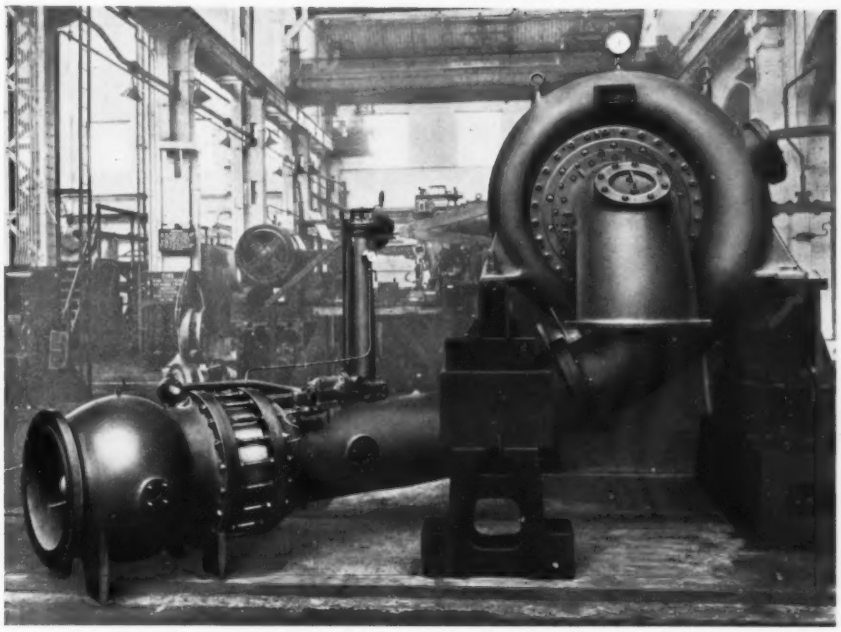


Fig. 5.—One of the 1,450 H.P. horizontal-reaction Water Turbines and cylindrical balanced Main valves, assembled at Rugby Works.

vided, so that each unit can be completely and independently isolated from the pipeline when required.

Fig. 5 shows the turbine assembled with inlet piping and main control valve at Rugby Works, whilst Figs. 6, 7 and 8 show the complete units on site. In the left foreground of Figs. 6 and 8 can be seen the turbine-driven oil pumping set for supplying oil to both governor and bearings, in the centre is the governor servomotor surmounted by the actuator, and in the right foreground are the duplex oil and water strainers. Through the latter passes the water for cooling the bearings and for cooling the air in the closed-circuit ventilating system of the generator.

Generators.

Each of the two generators has an output of 1,000 kW., 1,250 kVA. at 0.8 power factor, 3,300 volts, 50 cycles, and runs at 1,000 r.p.m. All rotating parts are designed safely to withstand an overspeed of 1,850 r.p.m.

The generators are of the horizontal salient-pole type fitted with two pedestal bearings on bedplate and with shaft extension to carry the turbine runner.

The stator frame is built-up of steel elements welded to form a rigid and strong frame. The steel wrapper plate is welded to the outer edges of the frame and forms an efficient chamber for conveying the air to the bottom chimney. The stator winding is of the basket type in open slots with two coil sides per slot, the whole winding being suitably braced to withstand stresses set up on short circuit. The ends of the machine are enclosed by segmented sheet-iron shields.

The rotor body consists of a high-grade steel forging in one piece with the shaft, and dovetail slots are machined in the periphery of the forging for retaining the poles and winding. The poles consist of steel laminations riveted between cast-steel endplates.

The field winding consists of copper strip wound on edge on a metal spool from which it is insulated by a mica lining. Fans comprising duralumin blades are provided at both ends of the rotor.

A flywheel consisting of rolled-steel plates is

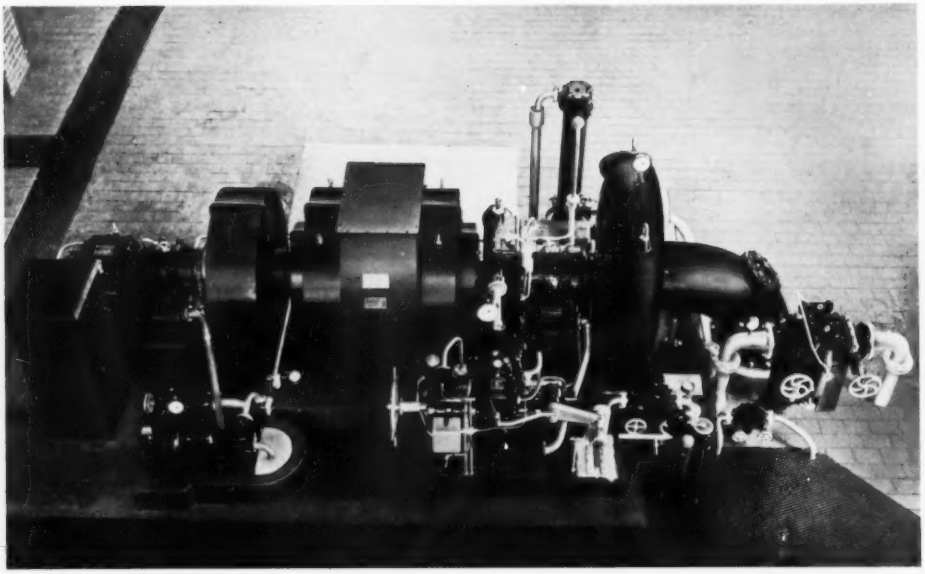


Fig. 6.—One of the 1,450 H.P. Generating Sets in the Power Station.

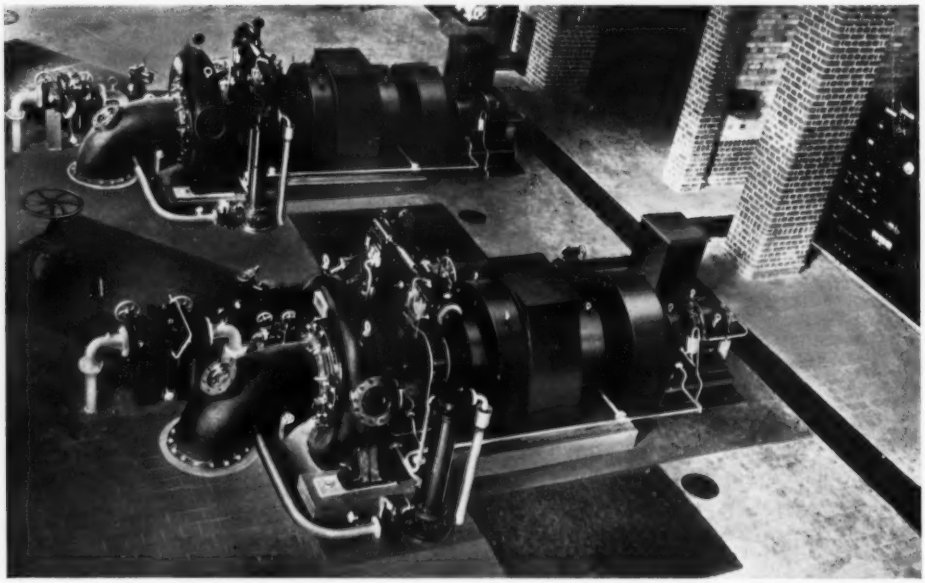


Fig. 7.—The Two Generating Sets viewed from turbine ends.

mounted upon the shaft at the slipring end of the machine between the rotor body and the bearing, and this, taken in conjunction with the rotor, provides an ample flywheel effect to fulfil the speed regulation guarantees. The inertia thus provided also allows a turbine relief valve to be dispensed with under the hydraulic conditions prevailing in the present case. The shaft is extended beyond the bearing to take an overhung-type exciter.

The pedestal bearings are of the ring-lubricated type and, as already stated, the driving-end pedestal has incorporated in it a Michell type double-thrust bearing.

Both thrust and journal bearings are fed with oil from the turbine governing system, and a thermostat is provided in each to make contact at a predetermined temperature to shut down the set.

Ventilation is on the closed-circuit principle, the cooled air being drawn into the machine from an intake in the alternator pit, by the rotor fans, through fan shields bolted on to the end covers. The air is distributed through the machine to the bottom chimney, which is centrally situated between the fan shield openings. A short length of trunking connects the bottom chimney to the cooler, which stands on one side of the machine and is readily accessible to the station crane.

Plate No. I shows the general arrangement and Plate No. II the cross section of the hydro-electric unit.

Switchgear.

The power is transmitted from the generating station to the Falls Hotel at 3,300 volts, which is the generating voltage, and to Livingstone by means of a 22,000-volt transmission line.

The whole of the switchgear, transformers and connections for the power station and the two substations at Falls Hotel and Livingstone formed part of the Company's contract, and this equipment included the automatic control gear.

The 3,300-volt power station switchgear is of the built-up sheet-steel truck and cubicle type, totally enclosed and vermin-proof and arranged for floor mounting. The pillars are of the Commany's standard design and the oil-circuit breakers have a rupturing capacity of 50,000 kVA. Generator and feeder pillars are provided together with a metering cubicle and Merz-Price gear for the generator neutrals.

The control board consists of black enamelled slate panels and includes the automatic control panels, the generator control panels, and the exciter and automatic voltage regulator panels.

Other power station gear and equipment include the generator neutral earthing equipment, field suppression switch pedestals, station battery with control panel, trickle charger and motor-generator set, and 220-volt floor-mounting combination fuse switchboard.

Automatic Control.

The two generating units in the power station run unattended, the engineer in charge having his living quarters some six miles away.

For the present only one unit will be run at a time, but in future, when the load increases and further units are installed, automatic synchronising will be required, and the present control gear is so designed that this feature can be added with the minimum of disturbance.

Tests for automatic changeover from one unit to the other showed that only 2½ minutes is required to regain continuity of supply if one unit should fail.

The starting impulse is given by a push button on the control panel in the power station, and thereafter the running up of the turbine and the going into service of the generating unit is entirely automatic.

The sequence of operations is as follows :—

(1) On the starting impulse being given a master contactor closes.

(2) The closing of the master contactor causes the main valve to open slightly, allowing pressure to build up in the turbine spiral casing.

(3) The building up of normal working pressure in the spiral casing enables a pressure device to cause the main valve to be opened fully.

(4) When water is admitted to the spiral casing it is also admitted to the pump turbine and to the oil and air coolers. The pump turbine runs up and provides

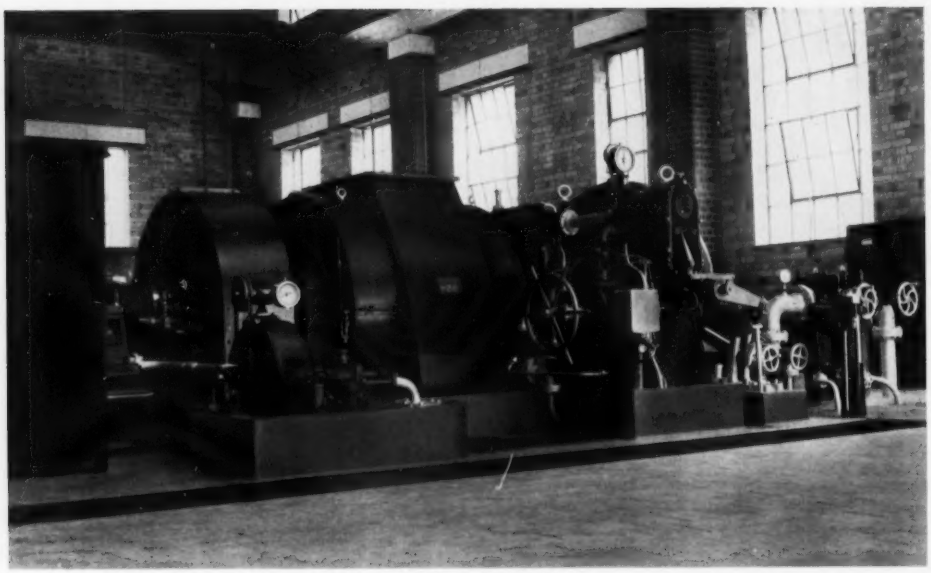


Fig. 8.—View of one of the Generating Sets showing Turbine Governor Gear.

pressure oil for the governor and bearings.

(5) Oil pressure being available, the governor takes limited control and starts gradually to open the turbine gates.

(6) The turbine begins to rotate and as a consequence :—

(*a*) The gear-driven oil pump starts to build up pressure.

(*b*) The field starts to build up, causing the voltage regulator to commence bringing the voltage to normal.

(7) The occurrence of oil pressure in the gear pump causes the turbine-driven pump to shut down.

(8) When the speed approaches normal the governor takes full control and the alternator voltage approaches normal.

(9) By means of a time-delay relay a steady condition is attained, whereupon the solenoid of the main oil-circuit breaker is energised, the circuit breaker is closed, and the start is then complete.

For shutting down :—

(1) The master contactor is de-energised and this cuts off the protective circuits and closes the governor by means of its oil valve solenoid.

(2) At the same time the main valve closing contactor is energised, causing the valve to close by means of its motor.

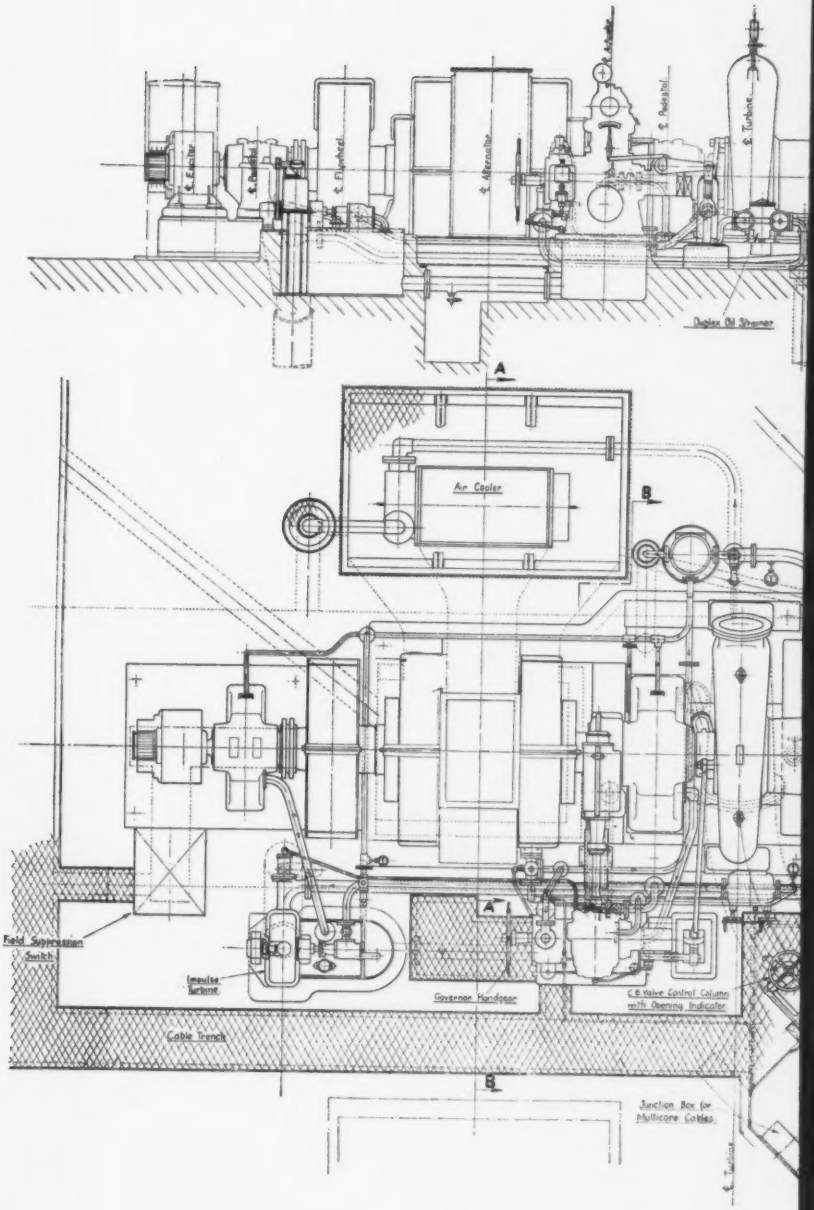
(3) As the governor closes, the turbine gates reach the no-load position and the main oil circuit breaker is tripped.

(4) When the main valve is fully closed a limit switch cuts off the valve motor and at the same time the oil-pump turbine comes to rest.

Protective Devices.

Automatic protection is given against any of the following :—

Sustained over-current.
Over-voltage.
Over-speed.
Alternator field failure.
Internal faults.
Overheated bearings.
Oil failure.
Exceeding of normal starting time.


Duplex Oil Strainer
A
Air Cooler
B
A
Field Suppression Switch
Impulse Turbine
Governor Handgear
G.V. Valve Control Column with Opening Indicator
Cable Trench
B
Junction Box for Multicore Cables

Plan and Ele

FALLS HYDRO-ELECTRIC SCHEME

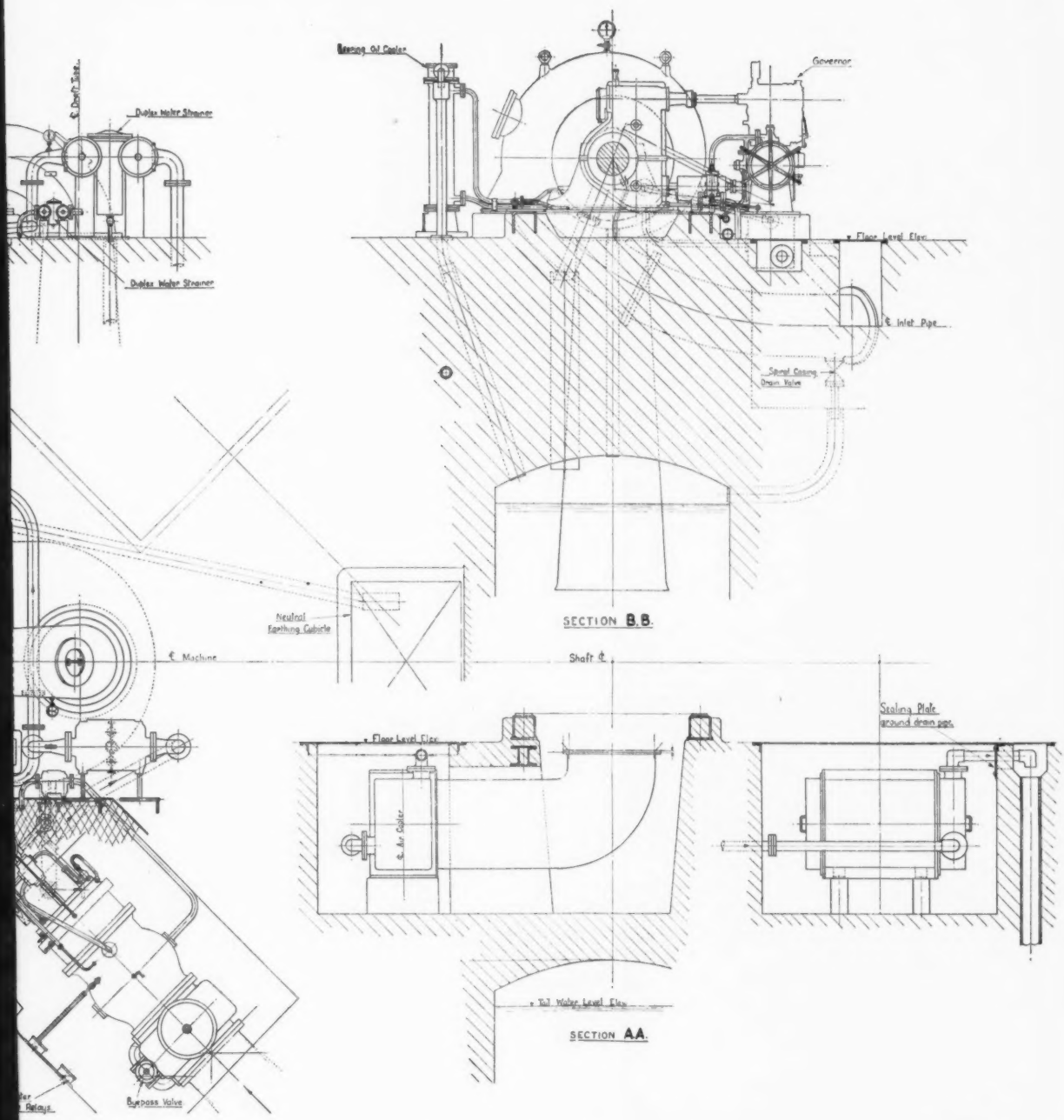
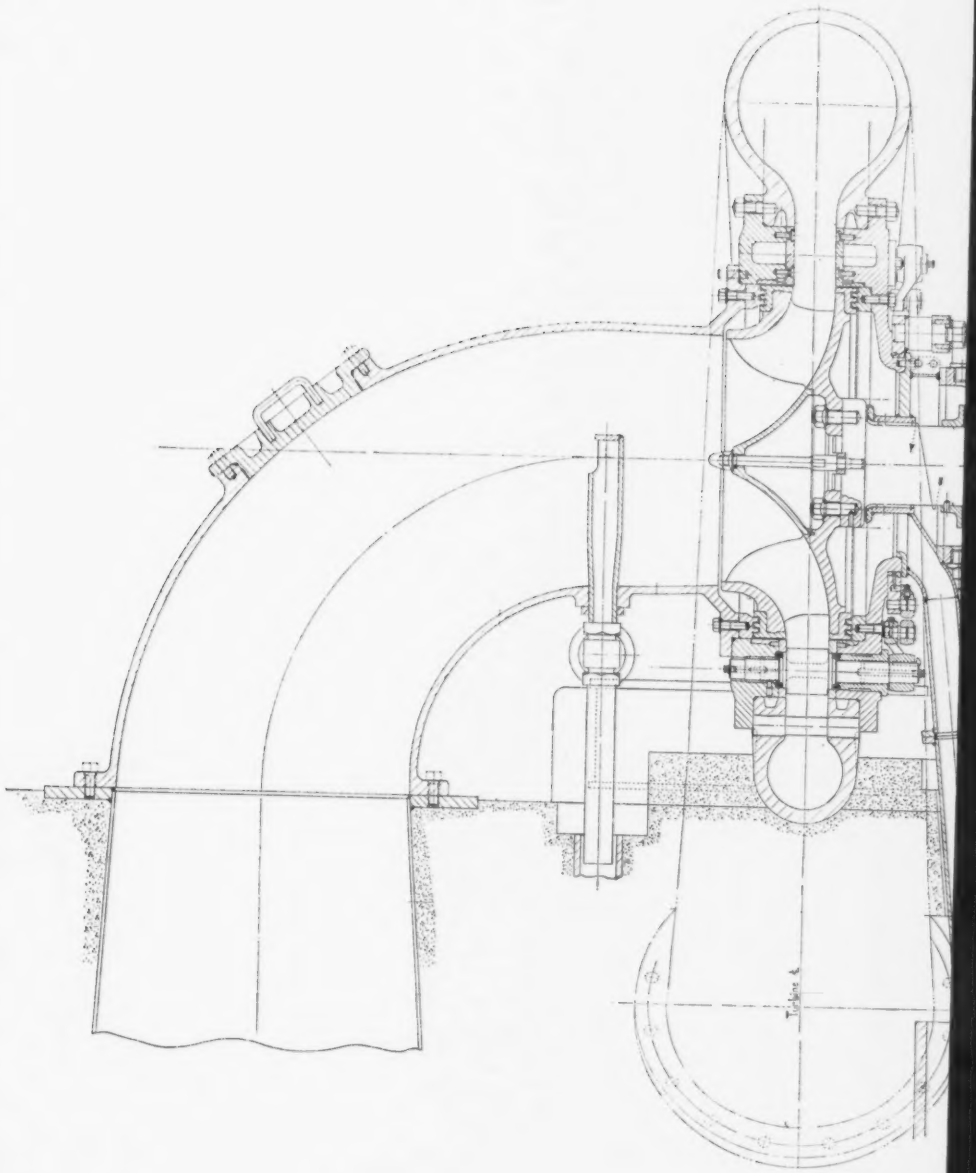


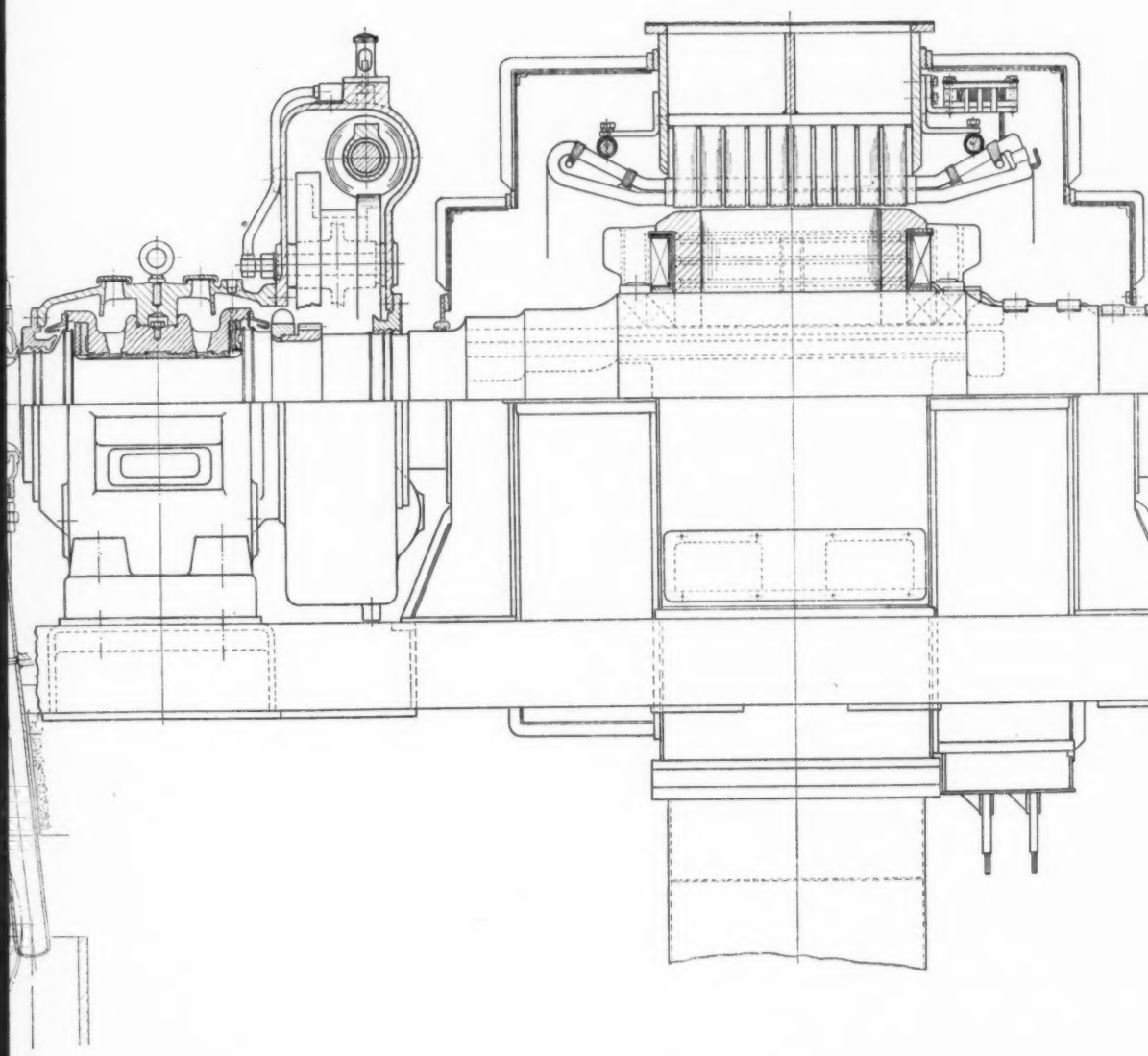
PLATE I

ation of a 1,000 kw. Hydro-Electric Unit.

[The English Electric Journal.



THE VICTORIA FALLS HYDRO-ELECTRIC SCHEME



Cross Section through 1,000 kw. Horizontal-Reaction Water Turbine and Alternator

EME

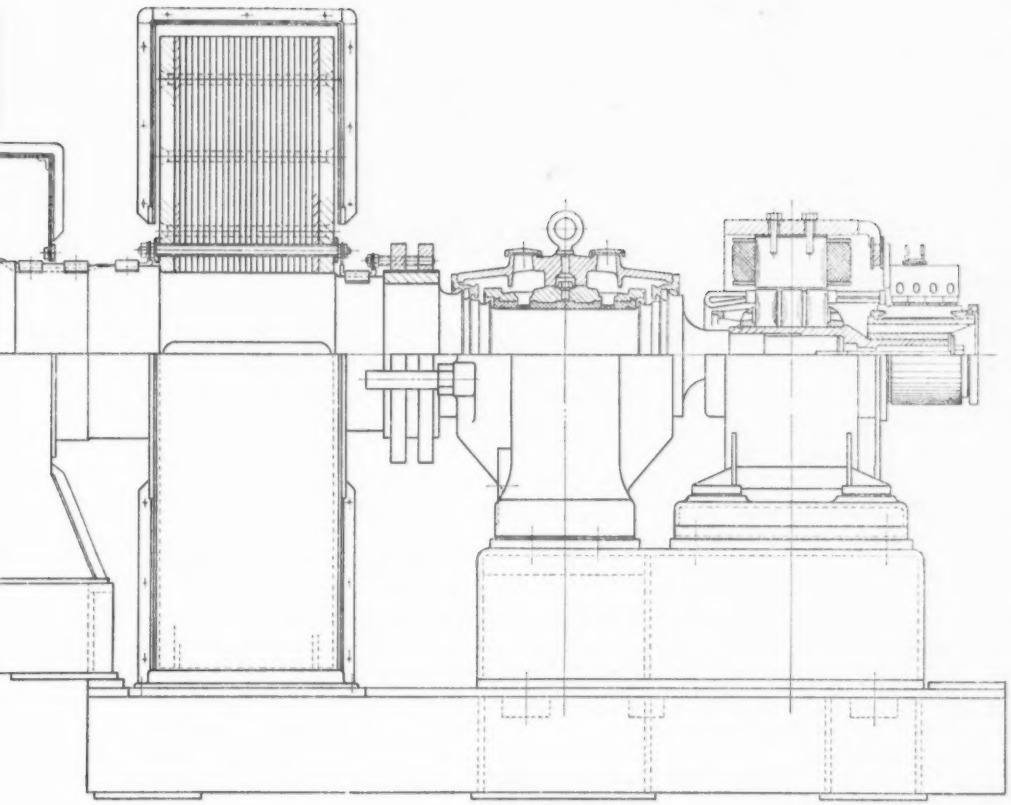


PLATE II

ator.

Fig. 9.—The Main Falls.

Any of the aforementioned would cause the unit to shut down and the main oil switch to trip.

In the event of the running machine shutting down, the other machine will automatically come into operation.

When any further units are installed, the next machine will run up when the running machine approaches full load. This sequence will repeat as necessary until all available plant is running.

Substation Equipment.

At Livingstone the incoming 22 kV. supply is transformed down to 2,200 volts by means of two 750 kVA. 3-phase oil-immersed self-cooled indoor type transformers provided with on-load tap-changing equipment.

The 2,200-volt switchgear is of the truck and sheet-steel cubicle type comprising transformer and feeder pillars, metering equipment, and tap-change control cubicle. The equipment at the Falls Hotel substation comprises a 3,300-volt truck-type switchboard for controlling two 200 kVA. transformers of a similar type to those installed at Livingstone, and a tap-changing control cubicle is also provided.

For local distribution there is a combination fuse switchboard for the 400/230 volts, 3-phase system.

The Victoria Falls.

The erection and placing into service of the plant was carried out under the supervision of the Company's resident engineer, Mr. C. G. T. Clarke, who spent about 15 months on the site. During that time he had opportunities to study the Falls under all conditions, and we reproduce in his own words the following description. He also gives an account of his daring exploit in descending to the base of the Falls by rope, his pioneer exploration of the chasm, and the measurement taken in co-operation with the Survey Department of the Northern Rhodesia Government.

Mr. Clarke's Description.

The Victoria Falls are without question one of the scenic wonders of the world, and are of absorbing interest both to scientist and tourist.

The majestic beauty of the famous cataract, with its untamed forces, its rainbow hues, and its curtain of spray rising to a height of at least 2,000 feet above the chasm, together with the continual deafening roar from the impact of the water on rock have to be seen and heard to be fully appreciated.

There is no doubt that the origin of these falls is volcanic, created some time in the remote past

Fig. 10.—View from Cliff Side.

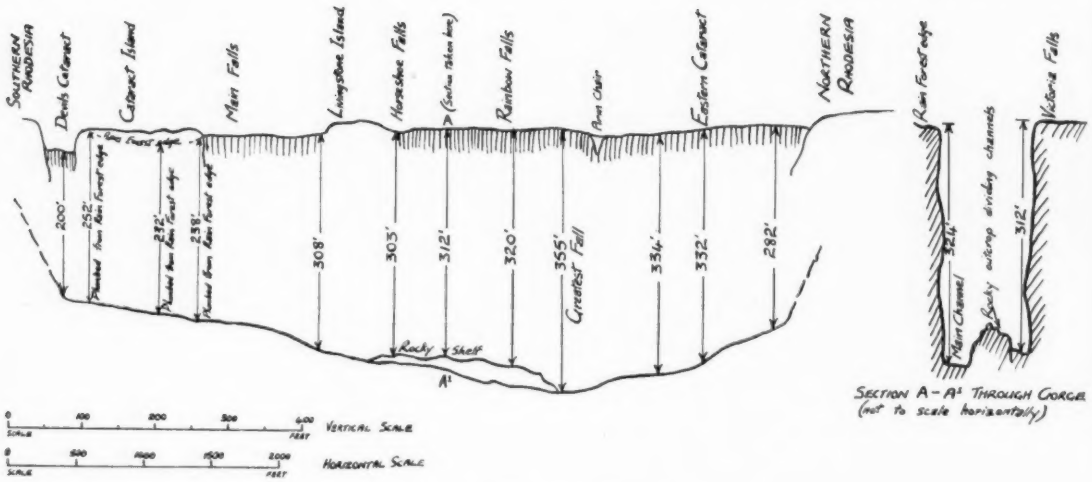


Fig. 11.—Elevation of Victoria Falls.

All vertical distances were plumbed, using graduated steel tapes and stations from which these were observed were connected and correlated by direct levelling.

Greatest Fall is 355 feet, and is directly opposite outlet to Boiling Pot. Devil's Cataract 200 feet. Main Falls 308 feet. Horseshoe Falls, Rainbow Falls and Eastern Cataract as shown on sketch. There is a drop of 140 feet between bottom of Devil's Cataract and the outlet, and a corresponding drop of 66 feet between the Eastern Cataract and that point. Similarly, the difference in level between the Outlet and the Boiling Pot is 10 feet.

River gauge at pumping station on 8th November, 1938, was 1.12 feet, and the plumbed height between mean railway rail level on the bridge and the water level in the gorge immediately below was 358 feet. For a portion of its length the gorge is traversed longitudinally by an abrupt rocky outcrop, thus dividing it into two sections. At the point where the above section was determined there was a difference of 15 feet between water levels in the two channels thus created.

(Signed) *C. G. T. Clarke,*
E. E. CO., LTD.
W. Younger,
SURVEYOR.

by a colossal earthquake. From a study of the contour of the surrounding country and its make-up, one comes to the conclusion that where the river, falls and gorge now are there existed a vast lake ; that is to say, the whole country in the vicinity of the Falls was under water.

Through the medium of a subterranean disturbance which rent the earth's crust, the lake was drained, and the water rushed in great torrents down what is now forty miles of gorge, leaving in its wake the crevice into which the Zambesi now plunges. This crevice is one and a quarter miles long, has an average width of 120 ft. and a maximum depth of 355 ft. At two-thirds

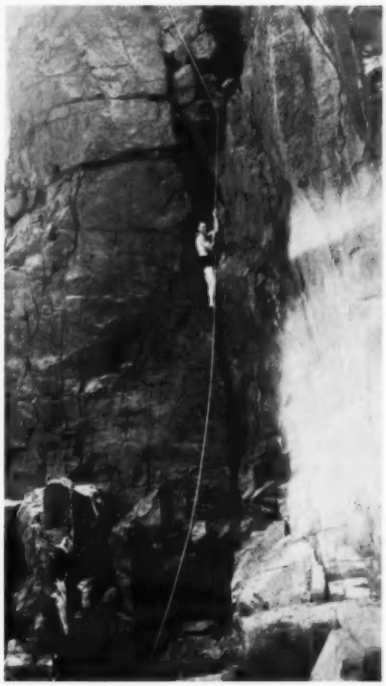


Fig. 12.—Mr. Clarke descending into the chasm.

of the way along it, from the west end, the gorge begins at a right angle to the horizontal plane of the falls crevice and continues for forty miles zigzagging through the country towards the Indian Ocean, when it opens out and eventually reaches the sea eight hundred miles away.

Rapids exist practically the whole way through the gorge, and the entire flow is nothing more or less than a torrent, especially during flood season from January to July.

Two miles downstream from the Falls the writer took some hydrographic data which are of interest, in that a cross-section of the river was taken at the part called " Silent Pool." Soundings were made 3 ft. apart across the river and in the same centre line as that of the turbine room of the hydro-electric power plant and the south bank of the river. The river bed recedes from the north bank gradually, then at two-thirds of the way across the maximum depth of 95 ft. was obtained ; the gradient to the surface on the south bank is very steep and the cliff side above water level is perpendicular. All readings were taken at minimum river level ; the average rise of the river at this spot is 50 ft., hence during flood season the maximum depth would be about 145 ft. Many other soundings were taken in the river at the " Silent Pool," and the average depth was found to be 66 ft. The north bank side, upstream from the power plant, has a sheer depth of 355 ft. at minimum flow.

On various occasions the face of the Falls was under careful observation to ascertain if it were at all possible to descend into the Falls chasm and to pass along the bottom. The result of this survey brought about a thorough investigation of the chasm into which the Zambesi plunges.

The writer, assisted by a young engineer, Mr. L. D. Maytham, succeeded in getting down by means of a rope in the vicinity of Main Falls and found a way along to Devil's Cataract. From the bottom of Main Falls it was seen that the vast column plunges on to solid basalt rock and is deflected at a right angle into the opposite bank.

Fig. 13.—Below the Main Falls.

Fig. 14.—The Eastern Cataract.

which is being undercut. Between Main Falls and Devil's Cataract there exists a small valley hitherto unseen by man, which presents a splendid spectacle of beauty with its carpet of maidenhair fern and overhung by evergreen trees. The spray from Devil's Cataract serves this glade as a natural water can, and the water drops sparkle in the brilliant sunshine which penetrates the trees.

At the bottom of Devil's Cataract the great pool is always kept in a very turbulent state by the ever-falling torrent, creating waves at least 2 ft. high on the far side of the pool, while the spray rises far above the precipitous sides and produces brilliant rainbows either by day or by night at full moon. The wedge-shaped crevice cutting into Cataract Island gives clear evidence of earthquake activity. It is only for a very short period of the year that water from the river pours into it, and this, together with its concave sides of hard basalt rock towering up some 250 ft. makes one realise the impossibility of it having been made by erosion. This crevice runs into the island for about 200 ft., and no doubt it still continues on in the same form though becoming narrower.

As it is not possible to penetrate the dense column of water and spray at the bottom of Main Falls, the writer made a careful survey of the face of the falls between it and the Eastern Cataract to ascertain if it was possible to descend into the chasm again by rope as was done from Cataract Island. There appeared to be only one place where an attempt could be made, and that was some two hundred yards to the west of the Eastern Cataract. Using the same rope attached to a tree on the crest of the falls, the writer and his assistant descended into the abyss hand over hand, and finally set foot on the bottom. There it was observed that in the base of the falls chasm the strata is vertical and runs parallel with the falls, yet the 300 ft. of basalt comprising the perpendicular face of the falls appears to be in five distinct layers in the horizontal plane, each layer being a shade different in colour.

After clambering over huge boulders the pool beyond the base of the Eastern Cataract was reached ; careful observation was made for the presence of crocodiles and on coming to the conclusion that there were none, a successful attempt was made to swim across. Cameras were towed in a water-tight tin. Then over more boulders to where the river leaves the falls chasm ; at this place the water is exceedingly turbulent, and tests were made for downward currents or suction, and as these tests proved satisfactory the attempt was made to swim across, and after a battle in swirling waters the rocky shelf was reached. This shelf runs along in front of the Rainbow and Horseshoe falls, and is broken only between these two cataracts. At this break a great difficulty arose ; the rocks were covered in green slime, kept wet by the spray from the Horseshoe falls. It was impossible to stand and the only manner in which to pass was to crawl, and even then the wind and spray tended to wash one off into the raging torrent from Main Falls. The shelf beyond was dry, so progress was made without hindrance until at the west end of the Horseshoe falls the very turbulent waters at the base of Main Falls were met. Here the situation became impossible. After several attempts to pass through the rapids, a rock in the river only a few feet from the eastern side of Main Falls was reached and this

Fig. 15.—At the foot of the Eastern Cataract.

spot marks the limit of approach to the base of this great cataract from the downstream side.

Now the entire base of Victoria Falls has been explored for the first time, and it can be said that there are no traces of animal remains along the base.

In conjunction with the Survey Department of the Government of Northern Rhodesia the various heights of the Falls were taken by direct plumbing. The Chief Surveyor, Mr. Younger, passed along the crest and let down a steel tape, and the writer went along the bottom in the manner previously described and took the tape to base level. In this way twelve readings were taken. The maximum height was found to be 355 ft., and this spot is at a place to the west side of the "Arm Chair." Devil's Cataract has a drop of 200 ft., while the Eastern Cataract is 282 ft. high.

The photographs and plan (Fig. 11) reproduced herein reveal the true nature of Victoria Falls.

A general survey was made to ascertain to what extent hydro-electric development could be carried on without interfering with the natural beauty of the Falls or the diversion of water therefrom. This revealed the possibility of drilling a tunnel from the "Silent Pool" into the pool at the bottom of the Eastern Cataract, a distance of about 400 yards. The entrance to this tunnel would at all times be below water level, hence never visible. The amount of power would depend on what quantity of water could be diverted down the Eastern Cataract. The present power station building would need extending to accommodate a large unit, but it would still be in harmony with the natural surroundings.

Fig. 16.—Rainbow Falls from the base.

The Thermodynamic Trend of Steam Turbine Practice.

By J. P. CHITTENDEN, M.I.Mech.E., A.M.I.E.E.,
and
J. T. MOORE, B.Sc., A.M.Inst.C.E.

Much has been written, and much without doubt will continue to be written, on the subject of high steam pressures and temperatures in steam turbine practice. The reason will be obvious from a consideration of the standard heat-entropy chart (Fig. 1), as this illustrates clearly that with an increase of pressure and temperature, the greater heat drops available increase much more rapidly than the total initial heat of the steam. This naturally permits of higher thermal efficiencies being obtained with consequent reduction in the coal bill. Thermal efficiency alone, however, is but one side of the story as a gain in thermal efficiency, for any reason, must become only of academic interest if the resultant savings are more than offset by increased capita' or maintenance charges.

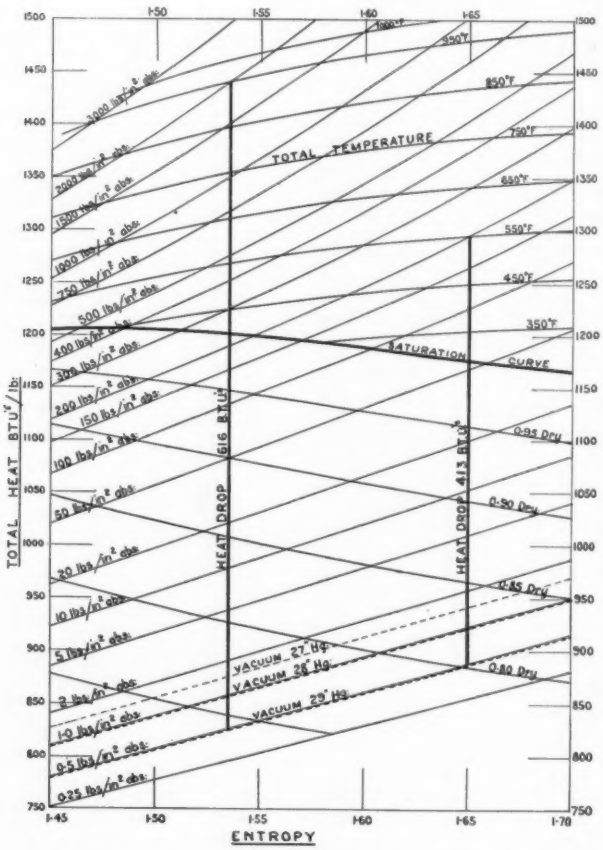


Fig. 1.—Mollier Diagram for Steam, illustrating increase of heat drop with increase of pressure and temperature.

The curves in Fig. 2, compiled from the latest (1939) issue of Callendar's Steam Tables, show the increases in adiabatic heat drop obtainable with increase in steam pressure and temperature, for various standard vacua. The gains, as will be noted, are very appreciable, especially at the higher pressures. The curves, while, it is hoped, proving useful to our many readers, illustrate more clearly than any explanation why the use of high steam pressures and temperatures continues to receive the closest attention from both turbine user and turbine builder.

Although progress in this country in the use of high steam pressures and temperatures has not been as great as in America and on the Continent, there are very sound reasons for this. Turbine

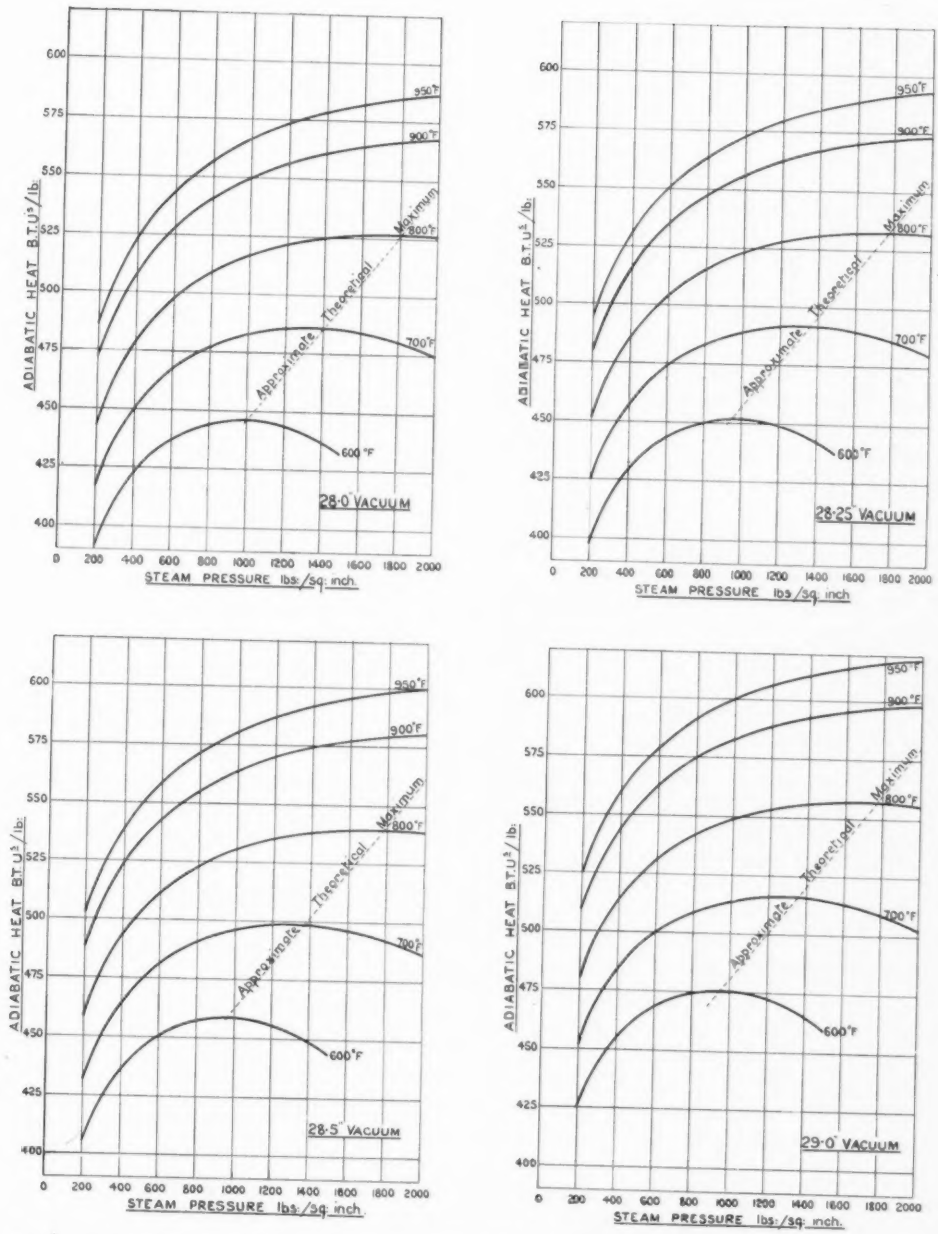


Fig. 2.—Curves illustrating the increases in adiabatic heat drop obtainable with increase in steam pressure and temperature, for various standard vacua.

users and turbine builders have always been fully alive to the advantages of high pressures and temperatures, but in this country the load density, except in certain cases, has not been sufficiently great in the past to justify the adoption of extra-high pressures and temperatures for the sizes of units in question. It naturally follows, with the adoption of higher pressures and temperatures, that costs of boilers, turbines and accessory equipment increases, and greater care is required for operation. These conditions have applied from the earliest days of the turbine industry, but progress has been steady, and will continue as materials and machine tools continue to improve, enabling machines and equipment to be produced which are equally as reliable as lower-pressure plant and at prices which justify the adoption of higher pressures and temperatures on commercial grounds.

The curves in Fig. 2 give a too optimistic picture of the gains which are obtainable with increased pressures and temperatures, as the theoretical gains cannot be fully realised unless the individual size of the machines increases almost correspondingly. For example, a 10,000 kW. turbine for steam at, say, 200 lbs. pressure would have a much lower efficiency if designed for steam at 2,000 lbs. pressure, on account of the very small blade heights due to the much smaller specific volume of the steam and the smaller steam quantity. Thus the higher the steam pressure, the greater the output of the turbine for approximately the same efficiency. This is but one of the factors which, in this country especially, has influenced to a large extent the adoption of high pressures.

Again, with increased pressure, the temperature must be correspondingly high to limit losses and erosion due to the moisture content in the steam at the low-pressure end of the turbine. Alternatively, with the temperature kept comparatively low, inter-stage reheating in some form becomes necessary. In the former case, existing materials limit the permissible temperature, and in the latter the cost and complication of the reheating plant precludes its use except on units of comparatively large output. It will thus be realised that increase of steam pressure gives rise to many other questions affecting directly the reliability as well as the cost of the plant.

A further consideration, load factor, comes into question very much in this country. In a large densely populated area it is a simple matter, under "Grid operation," to arrange for certain stations to carry the base load of the area, while others take the main variations in the load. In such circumstances the base load plant operates on a comparatively high load factor, and thermal efficiency becomes of the first importance, so that the more expensive plant for high pressure and temperature is more often justified by the thermal gains obtainable. On the other hand, with stations not operating under a high load factor, the more expensive plant cannot always be justified, more especially as the individual size of the units is generally smaller than in the base load stations.

The above are but the more important factors influencing the choice of steam conditions for turbine plant, and apply not only to the turbines, but also, to an almost equal degree, to the boiler plant. Having in mind the widely spread loading in this country, and the fact that the total load, even in the industrial areas, is not so high that a great number of large units can be justified on the grounds of flexibility on the Grid system as a whole, it is not surprising that a middle course has been largely adopted in this country. The most widely used pressure is now of the order of 600 lbs. per sq. inch, with a corresponding temperature of 850 deg. F. or thereabouts, and for some time to come these conditions will undoubtedly remain the most generally popular for the great majority of stations employing generating units of about 30,000 kW. individual capacity.

It must not be thought, however, that because conditions in this country do not at the moment justify the wide adoption of extra high pressures and temperatures, that the turbine user and the turbine builder are content to let the question remain in the background. No one is more interested in higher thermal efficiencies than the turbine user, and the turbine builder must

continually be seeking means of improving the overall performance of turbine machinery, firstly, by improvements in design enabling higher thermodynamic efficiencies to be obtained under recognised standard steam conditions, and, secondly, by developing and testing machines to utilise extra-high pressures and temperatures while still keeping first costs within reasonable limits.

Much work has been done on the above lines, and already there are in operation in this country a number of steam turbine plants utilising extra-high pressure steam, while further machines are in course of construction for stations where extra-high steam pressure can be economically justified. The English Electric Company has always taken a leading part in the development of steam turbine plant for high steam pressure and temperature conditions, and for many years their 1,100 lbs./sq. inch, 2,500 kW. back-pressure turbine, set to work at the Valley Road Power Station of the Bradford Corporation in 1929, was the only extra-high pressure plant in service in this country. To-day the Company has under construction a 10,000 kW. back-pressure turbine and a 25,000 kW. condensing turbine for initial steam conditions of 1,200 lbs./sq. inch, 900 deg. F., and also a 32,000 kW. turbine for initial steam conditions of 1,300 lbs./sq. inch, 950 deg. F. These will be outstanding pioneering units in their respective fields, the former two being for installation in the Power Station of the Balmain Electric Supply Co., Ltd., Sydney, Australia, and the 32,000 kW. set is for the Willesden Power Station of the Northmet Supply Company, Limited, London.

That turbines for the above operating steam conditions are now a commercial proposition when load conditions justify their installation is due in no small measure to the work of the metallurgist. The development of molybdenum steels has made possible temperatures much in excess of anything considered safe even only a few years ago, and a typical example of recent advances in high temperature steels is given in Fig. 3. The curves are only approximate, but show clearly the effect of temperature on a plain carbon steel and how the

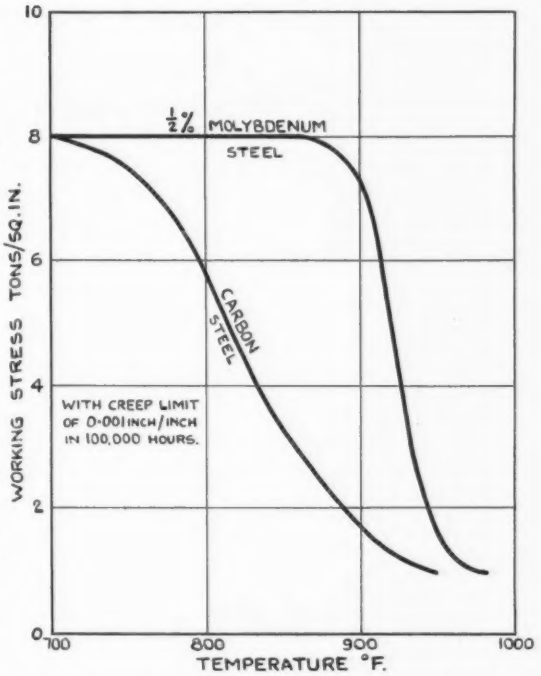


Fig. 3.—Curves showing the effect of temperature on the strength of plain Carbon Steel as compared with ½% Molybdenum Steel.

creep properties are improved by the addition of a small percentage of molybdenum.

With the advances which have taken place in steels for high temperatures, the adoption of higher steam pressures and temperatures will undoubtedly become more general, especially as the individual sizes of units increase with the rise in the total electrical load over the country. In this connection it is interesting to note the progress made in sizes of units and in operating steam pressures and temperatures over recent years. Fig. 4 illustrates the growth of the 3,000 r.p.m. turbine in this country, and has been based on the turbines supplied up to date by the Company. By the use of extra high pressures, the individual outputs of machines will continue to increase.

The corresponding change in operating steam pressures and temperatures since the early part of the present century is shown in Figs. 5 and 6. Both sets of curves have been based, as in Fig. 4,

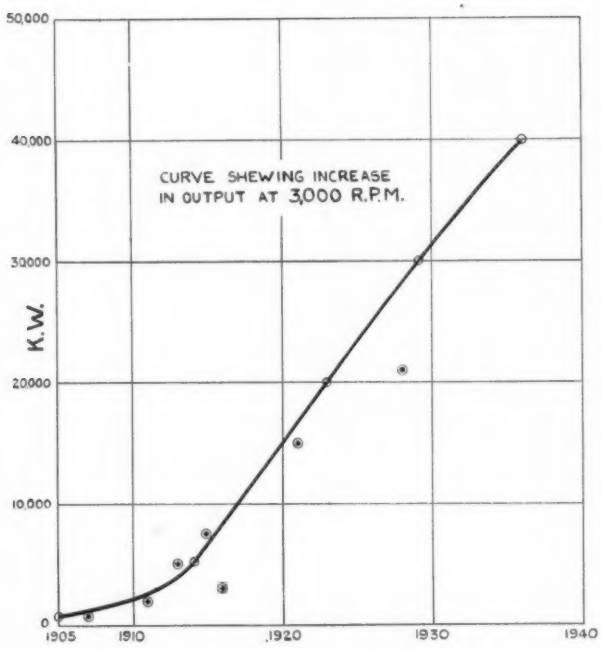


Fig. 4.—Curve showing increase in outputs (1905-1939) of "English Electric" turbines operating at 3,000 r.p.m.

on the steam turbine plant supplied by The English Electric Company and at present on order, but are representative of the steady rise over past years of normal steam pressures and temperatures in this country. Although pressures and temperatures of the order of 1,300 lbs./sq. in., even up to 1,800 lbs./sq. in., and 950 deg. F. respectively are accepted facts in this country to-day, they are by no means general, even on large units, but the curves are an interesting indication of the present trend.

A comparison of Figs. 4, 5 and 6 demonstrates the point, mentioned previously, that the size of individual units has a direct bearing on the adoption of higher pressures and temperatures. This is primarily due to questions of first cost, but the fact must not be overlooked that the lower steam consumption per kilowatt with increased pressures and temperatures enables greater outputs to be obtained from particular frame sizes without increasing the length or speed of the blades at the low-pressure end of the turbine. Moreover, with increased pressures and temperatures, the degree of feed-water heating is generally increased, still further reducing the quantity of steam per kilowatt flowing to the condenser. Fig. 7 illustrates, as an example, the range of output obtainable with different initial pressures and temperatures and corresponding average degrees of feed heating, with a fixed exhaust leaving area on a normal 3,000 r.p.m. turbine. In other words, substantially the same low-pressure end can give, with a vacuum of 28.5 ins., only about 24,000 kW. with steam conditions of 200 lbs./sq. in., 550 deg. F., and feed heating to 160 deg. F., whereas with initial conditions of 2,000 lbs./sq. in., 950 deg. F. and feed heating to 360 deg. F., it is suitable for about 39,000 kW. This illustrates also a secondary, but very important, ad-

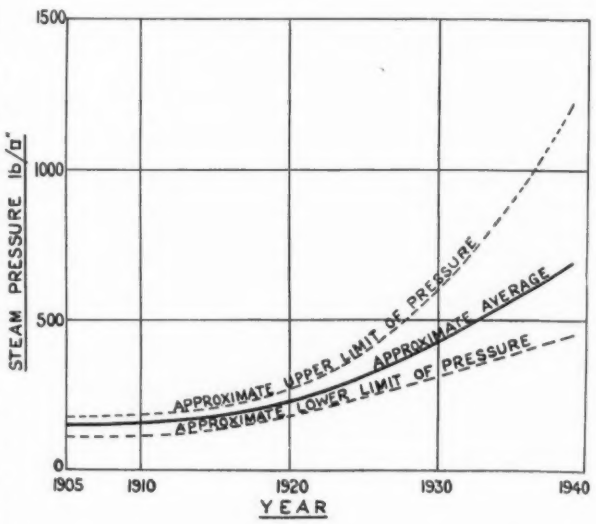


Fig. 5.—Increase in initial steam pressure on "English Electric" turbines (1905-1939).

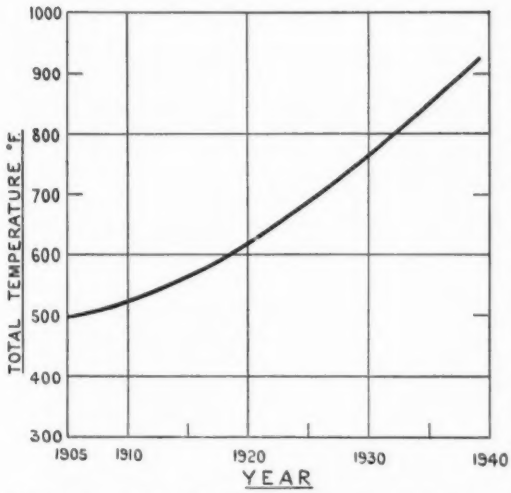


Fig. 6.—Increase in initial steam temperature on "English Electric" turbines (1905-1939).

vantage of high pressures and temperatures, namely, the smaller space and building requirements per kilowatt installed. In the modernisation of existing power stations, this might be a determining factor in the choice of steam conditions when as great a capacity as possible must be installed in the available space.

Finally, the smaller steam flow to the condenser with increased pressures and temperatures, and feed heating to a correspondingly high degree, naturally has a direct effect on the cooling water requirements. In all cases it must result in lower pumping costs, less costly pumping plant, and smaller cooling towers should these be required. Where water is scarce, the importance of this advantage of higher pressures and temperatures will be appreciated.

Taking all factors into consideration, there are abundant reasons for the turbine user and the turbine builder paying the closest attention to the use of high steam pressures and temperatures in steam turbo-generating plant. While the general adoption of pressures much in excess of 600 lbs./sq. in. does not appear to be justified in this country at the present time, there seems to be little doubt that higher pressures will become much more general in the future when conditions develop sufficiently to justify their adoption.

The present state of war, however, will naturally retard development, and during the period of hostilities it is unlikely that the use of higher pressures and temperatures will extend appreciably in practice, although research must continue.

On the other hand, if history repeats itself, the years immediately following the conclusion of hostilities should see very considerable developments in steam turbine practice, more particularly on higher steam pressures and temperatures.

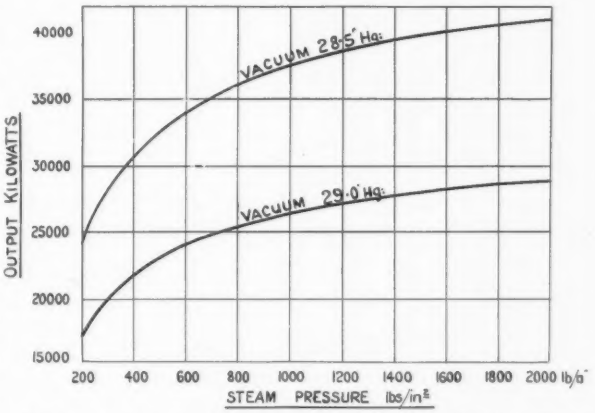


Fig. 7.—Curves illustrating range of output obtainable with a particular frame size of turbine under different operating steam conditions.

"English Electric" Equipment in the Wide Strip Hot Mill of Messrs. Richard Thomas & Co. Ltd., Ebbw Vale.

By H. S. CARNEGIE, M.I.E.E., Chief, Special Engineering Section.

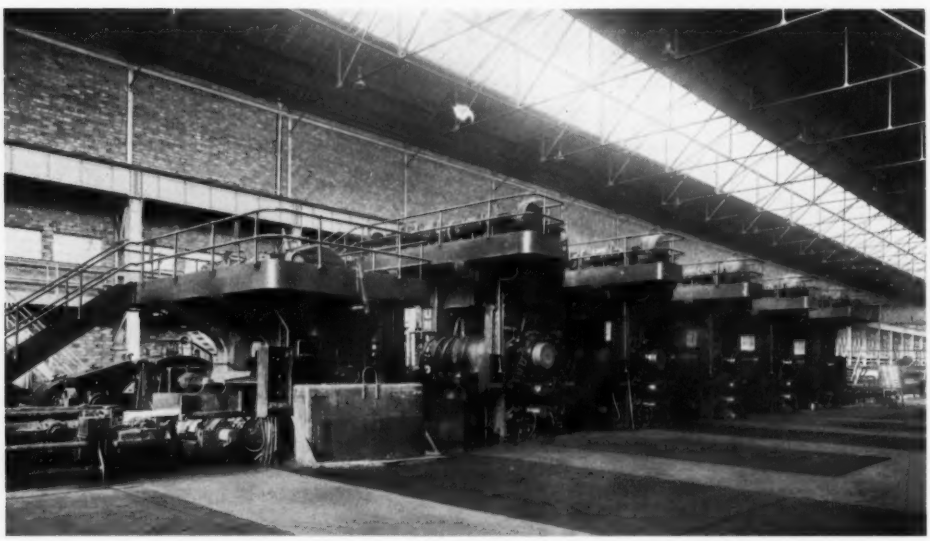


Fig. 1.—Scale Breaker and five 4-high Stands for wide strip hot finishing mill.

The town of Ebbw Vale has possessed iron and steel works for the past 150 years or so, but now, due to the enterprise of the management of Messrs. Richard Thomas & Company, Ltd.—to whom we are obliged for permission to publish this information—possesses a most up-to-date steel works for producing finished sheet and tin plate from the raw materials.

The operation of the rolling mill for producing such materials by the most modern methods calls for the best possible practice in electrical engineering, both as regards the machines employed and the apparatus to control them. An example is furnished by the main drives for the hot strip finishing mills manufactured and installed by The English Electric Company, of which a description is given herewith.

It will be as well perhaps to outline the method of production of the strip before proceeding with the detailed description of the plant. After the blooming down of the ingot to slabs, which vary up to 52 in. wide, 6 in. thick and 18 ft. long, they are charged into two continuous furnaces, each with a capacity of 60 tons an hour, the hot slabs being discharged over skid plates on to the live roller table on which they are conveyed to the roughing stands of the hot mill.

The slab first passes through a roughing scale breaker where the loosened scale is removed by hydraulic sprays, then through the slab squeezer,

which straightens the slab and, if required, reduces the width, after which it passes through three 2-high roughing stands, followed by a fourth 4-high roughing stand, two of these being fitted with edging rolls.

The roughing stands are spaced far enough apart so that the slab is rolled in one stand only at a time; consequently, the stands can be driven by single-speed motors, the four stands each being equipped with a 2,500 h.p., 500 r.p.m. synchronous motors. The edging rolls are driven by 200 h.p. direct-current motors.

The piece which is now $\frac{1}{2}$ in. to $\frac{3}{4}$ in. thick is then delivered on to a delay table extending 160 ft. between the last roughing stand and the finishing scale breaker. The delay table is fitted with drives enabling the strip to be moved to and fro under the action of air cooling to ensure the correct temperature on all parts before the piece enters the vital finishing passes. The finishing train consists of a 2-high scale breaker, followed by five 4-high finishing stands spaced as closely as practicable, the strip being rolled in all the finishing stands simultaneously, to a finished thickness as required, ranging from about ·05 in. to ·25 in. up to 50 in. wide.

The last finishing stand is followed by the flying shear, where the strip is cut into definite lengths, or, if the strip is to be coiled in one piece for further reduction, it travels over the long run-out tables, which are equipped with individually driven roller motors, on to one of two multi-motor hot-driven coilers where the strip, after coiling, is expelled and conveyed away for storage or for further treatment.

Particulars of these mills and drives are shown in the accompanying table on page 207; all mill rolls have a barrel length of 56 in.

The finishing stands, as viewed from the scale

Fig. 2.—One 2,800/3,080 H.P. and four 3,375/3,710 H.P. variable-speed Motors for Hot Finishing Mill.

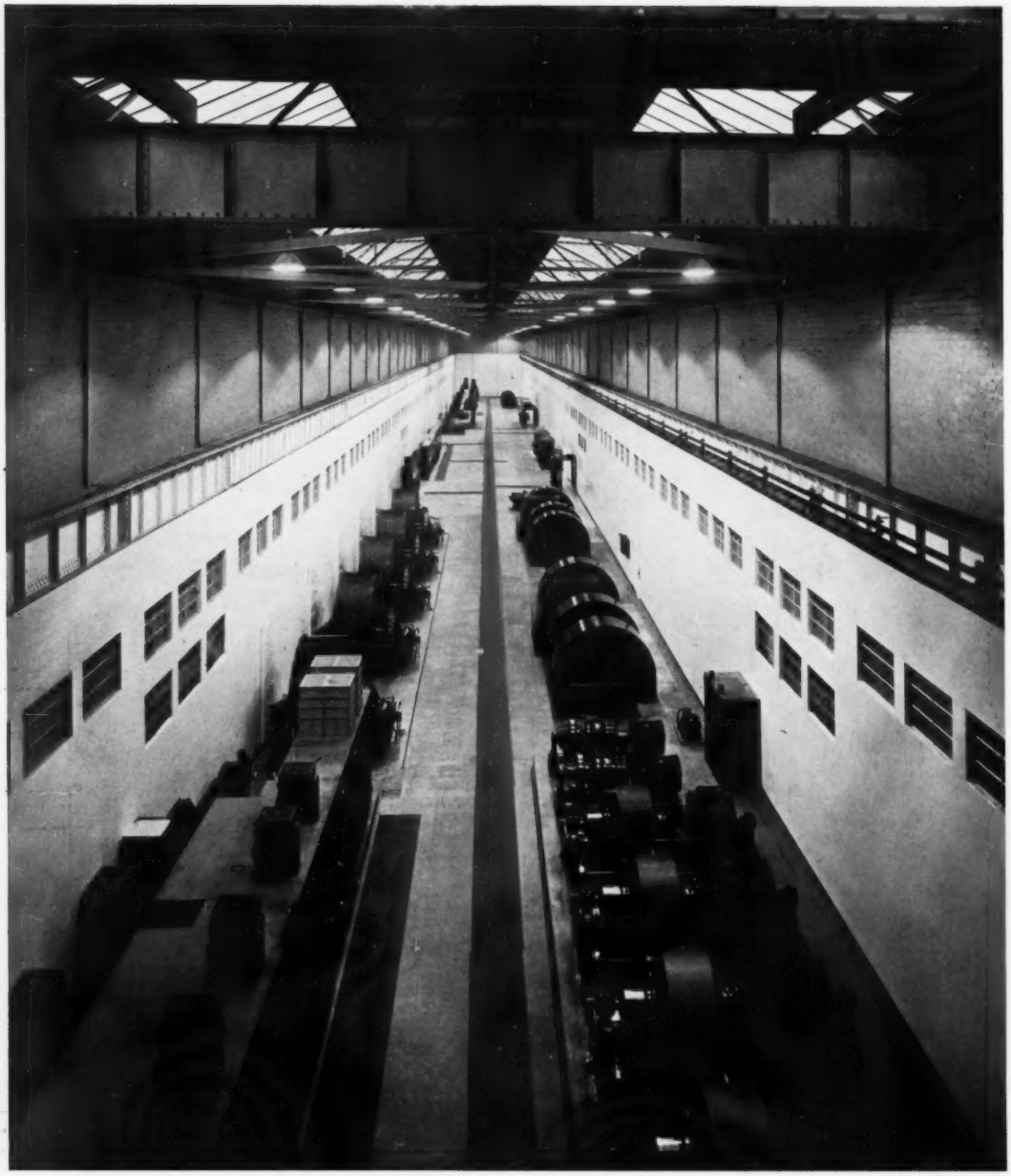


Fig. 3.—General view of Hot Mill Motor Room from finishing end.

Mill.	Work Rolls, diameter.	Gear Ratio.	Strip Speed, ft./min.	Motor H.P.	Motor R.P.M.	Average Percentage Reduction.
Roughing Scale Breaker	2-high 24″	17.55	179	600	500	9
No. 1 Rougher	2-high 32″	20	210	2,500	500	33
No. 2 Rougher	2-high 32″	20	210	2,500	500	38
No. 3 Rougher	2-high 32″	13.1	320	2,500	500	37
No. 4 Rougher	4-high 21″	6.4	420	2,500	500	36
Finishing Scale Breaker	2-high 24″	12.8	147/441	400	300/900	4
No. 1 Finishing	4-high 21″	4.4	281/562	3,375/3710	225/450	45
No. 2 Finishing	4-high 21″	2.75	451/902	3,375/3710	225/450	45
No. 3 Finishing	4-high 21″	1.89	654/1,308	3,375/3710	225/450	35
No. 4 Finishing	4-high 21″	1.52	815/1,630	3,375/3710	225/450	22
No. 5 Finishing	4-high 21″	Direct	925/1,850	2,800/3080	168/336	10

breaker, are shown in Fig. 1, each stand being spaced 18 ft. 6 in. apart, except for the first stand, which is 19 ft. 6 in. from the finishing scale breaker.

Due to these stands being at times connected together by the piece and the ratio of the peripheral speeds depending upon the draft in each stand, it is necessary to have very fine inherent regulation variable-speed motors. This necessitates the use of fully compensated and strengthened direct-current motors, with a small drop in speed between no load and full load.

All the six motors of the finishing train, together with the flying shear, when in use, are fed from common motor generator sets, so that by voltage control the speed of the whole mill can be varied as required, or started from zero and brought up to the correct rolling speed while maintaining the correct ratios between the stands.

As will be noted from the table, the gear ratio

Fig. 4.—Four variable-frequency Motor Generator Sets and Control Cubicles for run-out tables and multi-motor coilers.

Fig. 5.—Two 5,500 kW. Motor Generator Sets for finishing mill motors.

differs in the various stands, owing to the increasing strip speed as the section is reduced, the motors being of similar size and speed in four of the stands. In order to secure individual control for variation in draft or for the control of the strip between stands to prevent undue looping or tension, each motor is provided with a 2-1 speed range by field weakening ; the coarse speed control for general draft regulation being obtained by a motor-operated rheostat, while fine regulation for loop control is carried out from a lever-operated vernier rheostat. A close view of these large finishing mill motors is shown in Fig. 2, which also shows the volutes around each magnet frame to enable the motors to act as natural-ventilated machines which exhaust the warmed air downwards to be cooled in the basement, as referred to later.

All main drives are located in a long and well-finished motor room 560 ft. long by 45 ft. wide. Fig. 3 gives a view from the finishing mill end, the motor shafts project through the wall on the left-hand side, while the necessary motor generator sets are placed longitudinally in the room, as shown on the right-hand side of the illustration.

Two motor generator sets, which are illustrated in Fig. 5, each comprise an 8,000 h.p. 11,000 volt 750 r.p.m. synchronous motor driving three generators to give an output of 5,500 kW. at 550 volts on each set. All of these generators are paralleled, through electrically-operated circuit breakers, on to common busbars to supply the finishing mill train.

The main connections between the generators, busbars and motors are carried through two single-pole, electrically-operated circuit breakers for each machine, and in view of the concentration of direct-current power which might result in enormous short-circuit currents, the busbars and the two poles of the circuit breakers, which are of special high-rupturing capacity type, are spaced in two lines on each side of a gangway in the basement, as shown in Fig. 6. The generators are above one side of this basement and the motors above the other. This view was taken from the flying shear end, the two nearest circuit breakers supplying the two 90 h.p. flying shear motors. It will be

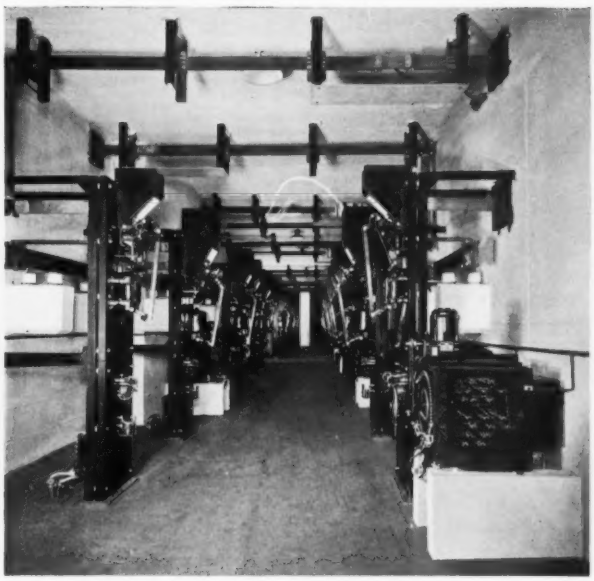


Fig. 6.—Electrically-operated Circuit Breakers and Busbar arrangement for Finishing Mill Motors and Generators.

observed that the busbars are spaced as widely apart as practicable, close to the wall on each side, with well-clamped and braced connections from the circuit breakers to their respective machines. The control circuits of these breakers can be preset from a control board located in the motor room between the roughing and finishing mills, as shown in Fig. 7 ; the board also containing the field switch for each motor.

This board is of the dead-front type and in the centre of the board will be observed the automatic voltage regulator, which maintains, *via* the generator exciter, a constant voltage on the busbars at any value that may be set by the operator. When the attendant has closed the necessary circuits from this board, further operation is carried out from the finishing mill pulpit (Fig.8). This allows the mill operator to trip or close the circuit breakers of all generators and all motors, raise the voltage of the system from zero to the operating value or to adjust it, and vary the speed of each motor in accordance with the rolling programme *via* the motor-operated rheostats and to operate the vernier rheostats for loop control by lever operation. This desk also includes the control of the looper rolls actuated by torque motors and the control of the flying shear, while indicating lamps show the operator when the generators and motors are available for use on the mill.

Between each stand are located the above-mentioned torque motor-operated looper rollers ; these torque motors are of the D.C. type, supplied from a special small looper motor generator set. The looper rollers are raised automatically by the passage

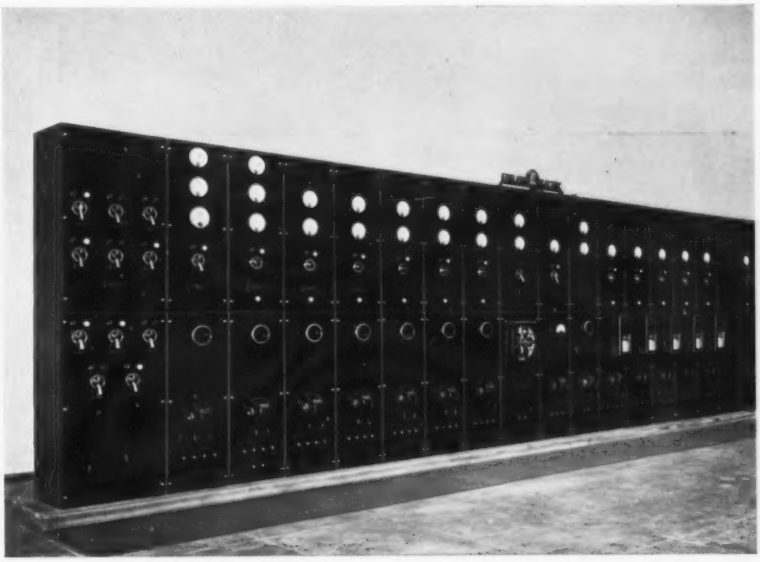


Fig. 7.—Dead-front Pre-setting Control and Instruments Board for Hot Finishing Mill Motors and Generators.

of the strip through the following stand, or they can be raised and lowered manually by control switches on the finishing mill pulpit.

On the right of Figs. 3 and 4 can be seen the four 350 kVA. variable-frequency motor-alternator sets driven by variable-speed D.C. motors, two of which feed two groups of the individual squirrel cage motor-driven run-out table rollers, while the other two supply the two multi-motor hot coilers, or, alternatively, in the case of a sheared strip being produced, feed the further individual-roller tables leading on to the piler equipment. Two further small motor generator sets are also located alongside these variable frequency sets, one to provide excitation for the variable-frequency alternators, the other to provide a low-voltage D.C. supply to the table and coiler motors for braking purposes.

Fig. 8.—Finishing Mill Control Desk for main motors, generators and looper apparatus.

The hot coiler is of special design, and Fig. 9 shows the coiler from the motor side, the coiling rollers being individually driven by flange-mounted special cooled, squirrel cage motors of 5/13½ h.p., each roller and motor moving outward as the metal strip is wound into a coil in the interior, the finished coil finally being ejected on the opposite side, as shown in Fig. 10.

The groups of coiler motors and run-out table motors are connected to the variable-frequency alternators at 20 cycles and are accelerated by the variation of the speed and, therefore, the frequency of the motor generator sets previously mentioned, the maximum

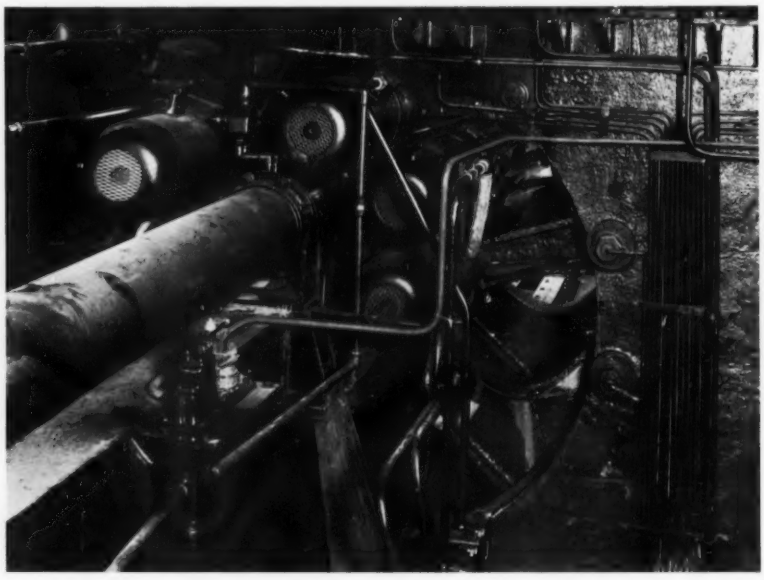


Fig. 9.—Multi-Motor Hot Strip Coiler showing flanged Coiler Motors mounted on Coiler Arms.

frequency being 53.5. This control is carried out from a desk overlooking the coilers and run-out tables. In order to bring the coilers or the run-out table motors to rest as quickly as possible, the motor alternator sets are decelerated to a low frequency, and just before the lowest speed is reached, the individual squirrel cage motors are disconnected in groups from their alternators and connected to the low-tension D.C. supply, which gives dynamic braking to rest. This method involves less heating of the motors than the alternative method of "plugging" them, i.e., reversing the A.C. supply on to the stators of the motors, but requires rather more apparatus.

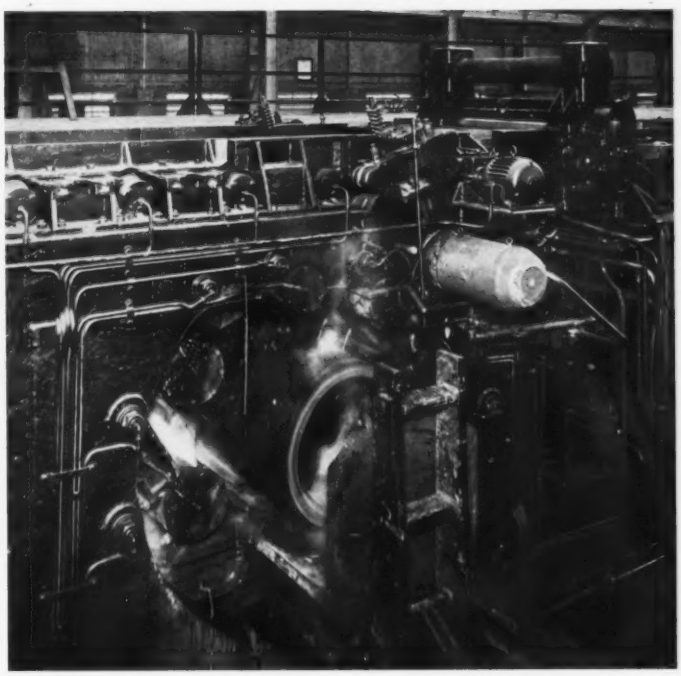


Fig. 10.—Hot Strip Coiler showing coil being ejected.

The apparatus for the control of the run-out table motors, coiler motors and piler table motors, is arranged in sheet-steel enclosed contactor cubicles of the back-to-back type as shown in Fig. 11.

Reference has been made to the ventilation of the motor room since it will be realised that in this room there is a total of over 70,000 h.p. of machines, many being continuously loaded, and consequently the losses from these machines would make the temperature of the room unbearable without adequate cooling equipment. The heat dissipated would require about 300,000 cu. ft. of air per minute to prevent an abnormal temperature rise in the motor room, and if this air were brought in through filters even of the most efficient type, there would be a continuous addition of suspended dirt, although of a small quantity at a time, part of which would be deposited on the machines and apparatus. The method adopted for the motor room has been to recirculate the air from the machines through tubular coolers placed in the basement and thence through fans discharging into ducts leading back into the machine house through openings in the walls, as can be seen in Figs. 3 and 4.

All machines are arranged to take air from the motor room and discharge it vertically down into the basement, the air being collected in tunnels in the case of the finishing mill equipment, with coolers at both ends. The house meantime is kept under pressure, to exclude mill dirt, by means of a small motor-driven fan with a self-cleaning filter of 50,000 cu. ft. per minute capacity. It will be noted, therefore, that the temperature of the air in the room is that of the cooled air and the temperature can be adjusted in the summer time by retaining the full water supply in the coolers, but in winter the water supply through these coolers can be restricted without interfering with the quantity of air circulated through each machine.

In addition to the apparatus illustrated and described in this article, The English Electric Company have supplied the electrically-operated circuit breakers for controlling the power from three 1,500 kW. 250 volt synchronous motor-

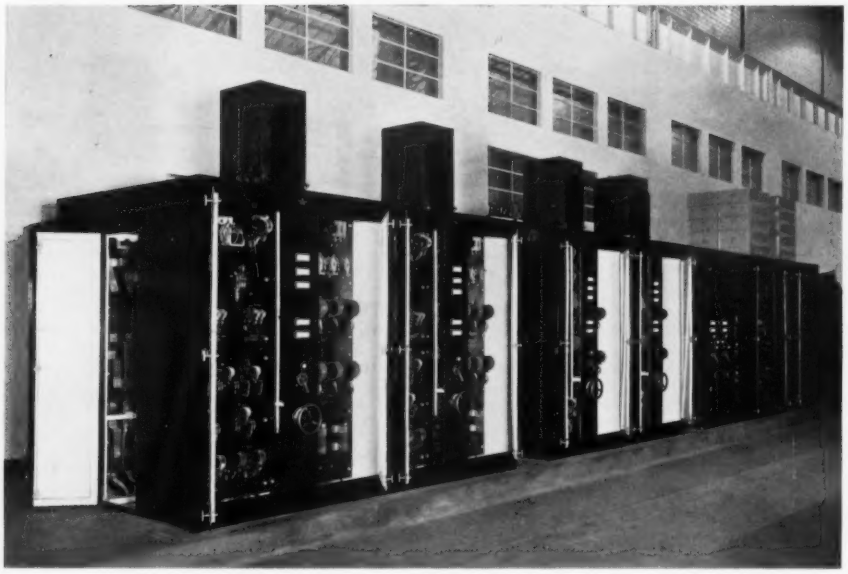


Fig. 11.—Back-to-Back Cubicles for variable-frequency Motor Generator Sets, run-out table motors and hot strip coilers.

generator sets to supply the large number of D.C. auxiliary motors in the whole of the mill. The circuit breakers are of the double-pole type and mounted in the basement under the motor-generator sets.

For the production of tin plate, the coils of strip are carried by an overhead conveyor across to the cold mill, where the Company have also supplied a considerable amount of plant, including the control equipment for three continuous electrolytic cleaning lines with tension winders at the end of each, and three temper pass or skin pass mill drives with very special tension control. These will be described and illustrated in further articles.

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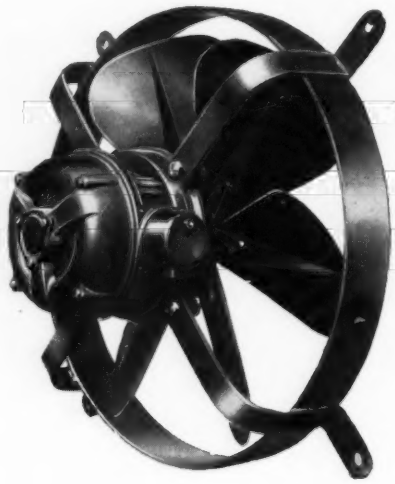

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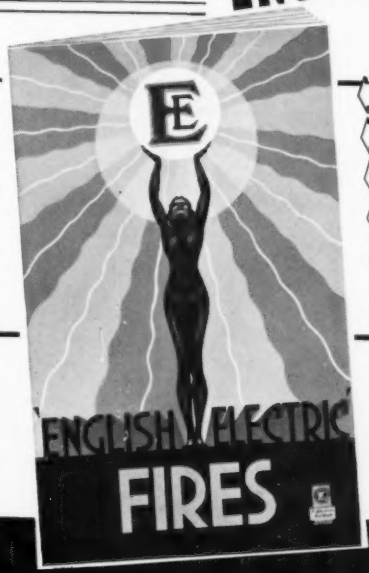

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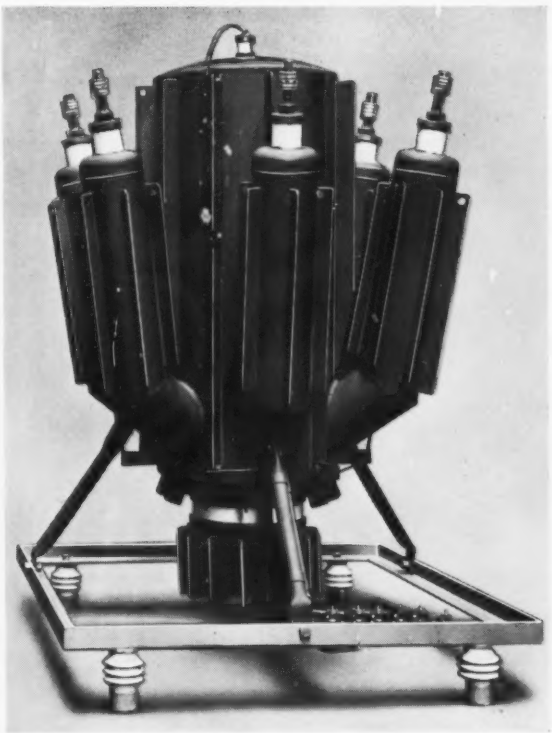

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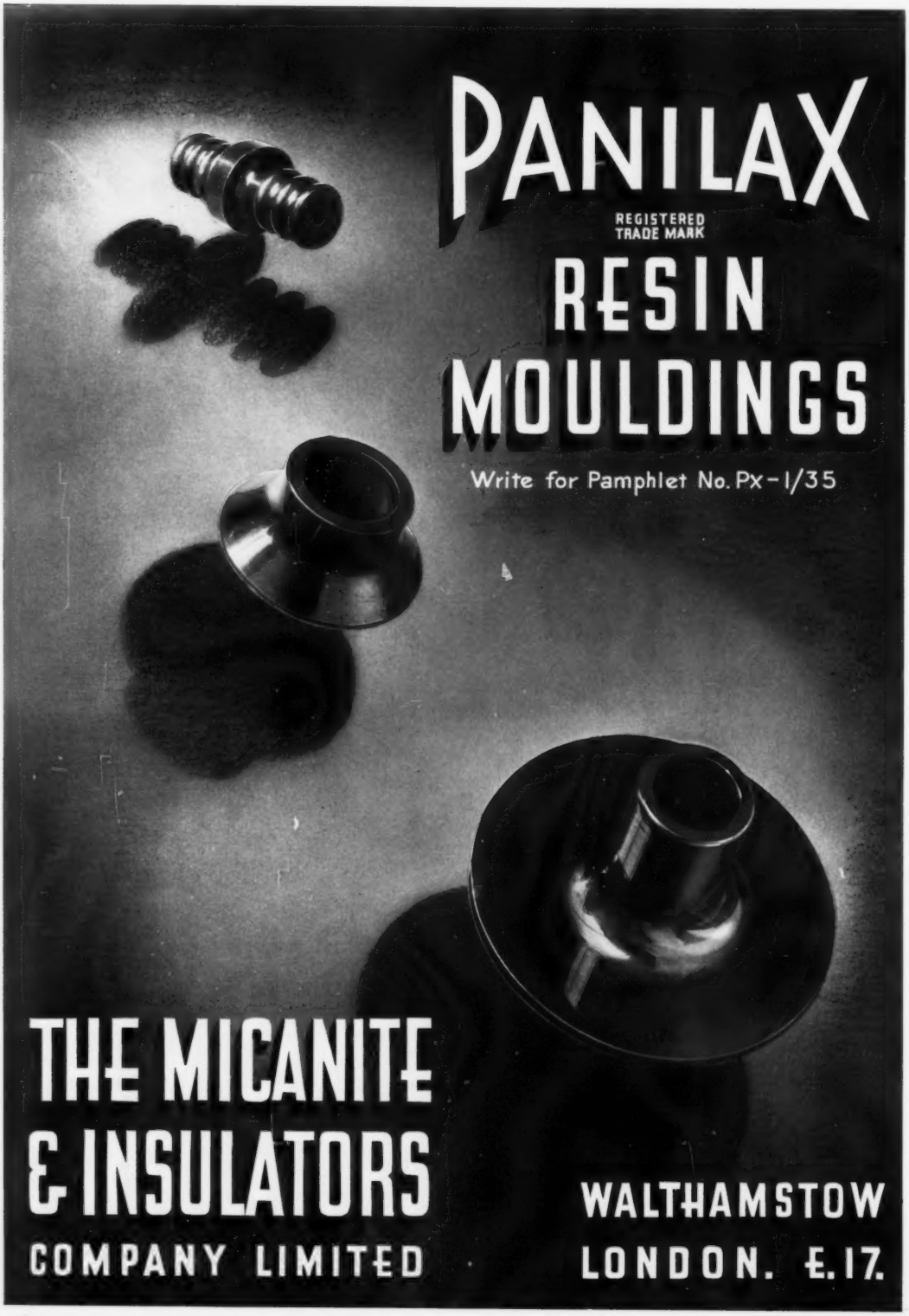
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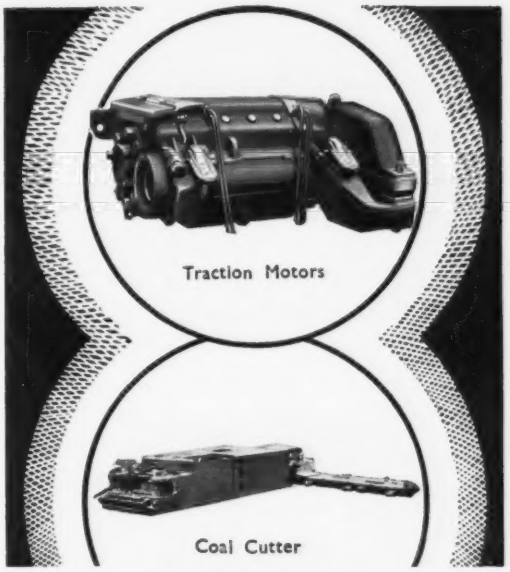

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